U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-245 988

PRELIMINARY INVESTIGATION OF EFFECTS ON THE ENVIRONMENT OF BORON, INDIUM NICKEL, SELENIUM, TIN, VANADIUM AND THEIR COMPOUNDS

VOLUME V - TIN

Versar, Incorporated

PREPARED FOR
Environmental Protection Agency

August 1975

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VOLUME V

TIN

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ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

PRICES SUBJECT TO CHANGE

AUGUST, 1975

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA-560/2-75-005e	2.	3. Recipient's Accession No.

4. Title and Subtitle

Preliminary Investigation of Effects on the Environment of Boron, Indium, Nickel, Selenium, Tin, Vanadium and Their Compounds - Volume V - Tin

5. Report Date

August 1975

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

Versar Inc.
6621 Electronic Drive
Springfield, Virginia 22151

10. Project/Task/Work Unit No.

2LA328

11. Contract/Grant No.

68-01-2215

12. Sponsoring Organization Name and Address

Office of Toxic Substances
Environmental Protection Agency
Washington, D.C. 20460

13. Type of Report & Period Covered

Final

14.

15. Supplementary Notes

16. Abstracts

A comprehensive review of published literature was conducted to prepare this preliminary investigation report on the physical and chemical properties of tin, on the environmental exposure factors related to its consumption and use, on the health and environmental effects resulting from exposure to this substance, and on any applicable regulations and standards governing its use.

17. Key Words and Document Analysis. 17a. Descriptors

Tin

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 06/F, J, T; 07/B i

18. Availability Statement

Release unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
113

22. Price

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

EPA-560/2-75-005e

PRELIMINARY INVESTIGATION OF EFFECTS ON THE ENVIRONMENT OF BORON, INDIUM NICKEL, SELENIUM, TIN, VANADIUM AND THEIR COMPOUNDS

Volume V

Tin

Contract No. 68-01-2215

Project Officer
Farley Fisher

Prepared for

Office of Toxic Substances
Environmental Protection Agency
Washington, D.C. 20460

August 1975

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VOLUME V

Preliminary Investigation of Effects on Environment of Tin and Its Compounds

FOREWORD

This is Volume V of a series of six reports on the environmental effects of boron, indium, nickel, selenium, tin, and vanadium and their compounds. The information is based on literature reviews, direct contact with representatives of companies invloved in the production or use of the materials, and consultation with knowledgeable individuals from industry, academic institutions and the Federal Government.

I. TIN INDUSTRY IN THE UNITED STATES

A. Producers and Location

The commercially significant tin products and the U.S. producers involved are given in Table 1.(1) For this study significant is defined as production exceeding 1/2 metric ton or $1,000 value. Other materials may also be included because of their unusual properties, or their anticipated future significance.

Table 1. (1)
Producers of Tin Compounds

	Producer	
Chemical	Company, subordination	Location
Barium stannate	NL Indust., Inc. TAM Div.	Niagara Falls, N.Y.
	Trenselco, Inc.	Penn Yan, N.Y.
Bismuth stannate	American Can Co., M&T Chems. Inc.	Carrollton, Ky.
	Transelco, Inc.	Penn Yan, N.Y.
Calcium stannate	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	NL Indust., Inc. TAM Div.	Niagara Falls, N.Y.
	Transelco, Inc.	Penn Yan, N.Y.
Cerium stannate	NL Indust., Inc. TAM Div.	Niagara Falls, N.Y.
	The Shepherd Chem. Co.	Cincinnati, Ohio
Cobaltous stannate	City Chem. Corp.	Jersey City, N.J.
Cupric stannate	City Chem. Corp.	Jersey City, N.J.
Lead (plumbous) stannate	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	City Chem. Co.	Jersey City, N.J.
	The Shepherd Chem. Co.	Cincinnati, Ohio

Table 1. (Con't)

	Producer	
Chemical	Company, subordination	Location
Magnesium stannate	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	NL Indust., Inc. TAM Div.	Niagara Falls, N.Y.
	Transelco, Inc.	Penn Yan, N.Y.
Nickel stannate	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
Potassium stannate	American Can Co. M&T Chems. Inc.	East Chicago, Ind.
	Vulcan Materials Co. Metals Div.	Pittsburgh, Pa.
Tin acetate (stannous)	City Chem. Corp.	Jersey City, N.J.
Tin bisacetylacetonate (stannic)	MacKenzie Chem. Works, Inc.	Central Islip, N.Y.
Tin bromide (stannic)	City Chem. Corp.	Jersey City, N.J.
Tin chloride (stannic)	American Can Co. M&T Chems. Inc.	Carrollton, Ky. East Chicago, Ind.
	Filo Color and Chem. Corp.	Newark, N.J.
	Mallinckrodt Chem. Works Indust. Chems. Div.	St. Louis, Mo.
	Richardson-Merrell, Inc. J.T. Baker Chem. Co.	Phillipsburg, N.J.
	Vulcan Materials Co. Metals Div.	Pittsburgh, Pa.
Tin chloride (stannous)	American Can Co. M&T Chems. Inc.	Carrollton, Ky. East Chicago, Ind.
	Filo Color and Chem. Corp.	Newark, N.J.
	Mallinckrodt Chem. Works Indust. Chems. Div.	St. Louis, Mo.
	Richardson-Merrell, Inc. J.T. Baker Chem. Co.	Phillipsburg, N.J.
	Vulcan Materials Co. Metals Div.	Pittsburgh, Pa.

Table 1. (Con't)

	Producer	
Chemical	Company, subordination	Location
Tin chloride dihydrate (stannous)	Vulcan Materials Co. Metals Div.	Pittsburgh, Pa.
Tin chloride pentahydrate (stannic)	American Can Co. M&T Chems. Inc.	East Chicago, Ind.
	Vulcan Materials Co. Metals Div.	Pittsburgh, Pa.
Tin chromate (stannous)	City Chem. Corp.	Jersey City, N.J.
Tin 2-ethylhexanoate (stannous)	American Can Co. M&T Chems. Inc.	Carrollton, Ky. Rahway, N.J.
	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio
	Tenneco Inc. Tenneco Chems., Inc. Intermediates Div.	Elizabeth, N.J. Long Beach, Calif.
	Troy Chem. Corp.	Newark, N.J.
	Witco Chem. Corp. Organics Div.	Clearing, Ill.
Tin fluoborate (stannous)	Allied Chem. Corp. Specialty Chems. Div.	Marcus Hook, Pa.
	Harstan Chem. Corp.	Brooklyn, N.Y.
	Kewanee Oil Co. Harshaw Chem. Co., div. Indust. Chems. Dept.	Cleveland, Ohio
Tin fluoride (stannic)	City Chem. Corp.	Jersey City, N.J.
	Ozark-Mahoning Co.	Tulsa, Okla.
Tin fluoride (stannous)	Allied Chem. Corp. Specialty Chems. Div.	Marcus Hook, Pa.
	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	City Chem. Corp.	Jersey City, N.J.
	Ozark-Mahoning Co.	Tulsa, Okla.
Tin iodide (stannic)	City Chem. Corp.	Jersey City, N.J.

Table 1. (Con't)

	Producer	
Chemical	Company, subordination	Location
Tin iodide (stannous)	City Chem. Corp.	Jersey City, N.J.
Tin Metal	Atomergic Chemetals Co. Div. Gallard-Schlesinger	Carle Place, N.Y.
	J.T. Baker Chemical Co.	Phillipsburg, N.J.
	Chemetron Corp. Inorganic Chemicals Division	Cleveland, Ohio
	Division Lead Co. Division Century Display Mfg. Co.	Summit, Ill.
	Electronic Space Products Inc.	Los Angeles, Cal.
	Engelhard Minerals & Chemicals Corporation	Murray Hill, N.J.
	Kawecki Berylco Ind. Inc.	New York, N.Y.
	Morris P. Kirk & Sons Inc.	Los Angeles, Cal.
	M&T Chemicals Inc. American Can Co.	Richmond, Cal.
	NL Industries, Inc. Metal Division	New York, N.Y.
	Texasgulf Inc.	New York, N.Y.
	Ventron Corp.-Alfa Products	Beverly, Mass.
	Vulcan Materials Co. Metals Div.	Sandusky, Ohio
Tin naphthenate	Troy Chem. Corp.	Newark, N.J.
Tin neodecanoate (stannous)	Mooney Chems., Inc.	Franklin, Pa.
Tin oleate (stannous)	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio
	Tenneco Inc. Tenneco Chems., Inc. Intermediates Div.	Elizabeth, N.J. Long Beach, Calif.
	Troy Chem. Corp.	Newark, N.J.

Table 1. (Con't)

	Producer	
Chemical	Company, subordination	Location
Tin oxalate (stannous)	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	City Chem. Corp.	Jersey City, N.J.
	Vulcan Materials Co. Metals Div.	Pittsburgh, Pa.
Tin oxide (stannic)	American Can Co. M&T Chems. Inc.	East Chicago, Ind.
	Chemetron Corp. Chems. Group Inorganic Chems. Div.	Cleveland, Ohio
	Filo Color and Chem. Corp.	Newark, N.J.
	Kewanee Oil Co. Harshaw Chem. Co., div. Indust. Chems. Dept.	Elyria, Ohio
	Transelco, Inc.	Penn Yan, N.Y.
Tin oxide (stannous)	American Can Co. M&T Chems. Inc.	Carrollton, Ky. East Chicago, Ind.
	Belmont Smelting & Refining Works Inc.	Brooklyn, N.Y.
	Kewanee Oil Co. Harshaw Chem. Co., div. Catalyst Dept.	Elyria, Ohio
	Vulcan Materials Co. Metals Div.	Pittsburgh, Pa.
Tin powder	Alcan Aluminum Corp. Alcan Metal Powders Div.	Elizabeth, N.J.
	Amax Metal Powders	Niagara Falls, N.Y.
	Atomergic Chemetals Co. Div. Gallard-Schlesinger	Carle Place, N.Y.
	Bram Metallurgical-Chem Co.	Philadelphia, Pa.
	Chemetron Corp. Inorganic Chemicals Division	Cleveland, Ohio
	Electronic Space Products Inc.	Los Angeles, Cal.
	SCM Corp. Glidden-Durkee Div.	Cleveland, Ohio

Table 1. (Con't)

Chemical	Producer Company, subordination	Location
Tin powder (con't)	D.F. Chem & Metal Corp., Goldsmith	Evanston, Ill.
	Morris P. Kirk & Sons Inc. N.L. Industries Inc.	Los Angeles, Cal.
	N.L. Industries Inc. Metal Division	New York, N.Y.
	United Mineral & Chemical Corp.	New York, N.Y.
	Ventron Corp.-Alfa Products	Beverly, Mass.
Tin pyrophosphate (stannous)	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	Ozark-Mahoning Co.	Tulsa, Okla.
Tin sulfate (stannic)	City Chem. Corp.	Jersey City, N.J.
Tin sulfate (stannous)	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	City Chem. Corp.	Jersey City, N.J.
	Vulcan Materials Co. Metals Div.	Pittsburgh, Pa.

Tin Compounds, Organic, Miscellaneous

Chemical	Company, subordination	Location
n-Butylstannoic acid	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio
Di-n-butyltin bis (2-ethylhexoate)	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio
Di-n-butyltin bis (isooctyl thioglycolate)	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio
Di-n-butyltin bis (n-lauryl mercaptide)	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio
Di-n-butyltin diacetate	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio

Table 1. (Con't)

	Producer	
Chemical	Company, subordination	Location
Di-n-butyltin dichloride	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio
Di-n-butyltin diisooctylthioglycolate	Anderson Dev. Co.	Adrian, Mich.
Di-n-butyltin dilaurate	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
	Anderson Dev. Co.	Adrian, Mich.
	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio
	Ferro Corp. Ferro Chem. Div.	Bedford, Ohio
	Mooney Chems., Inc.	Franklin, Pa.
Dibutyltin dilaurate mercaptide	Ferro Corp. Ferro Chem. Div.	Bedford, Ohio
Di-n-butyltin (2-ethylhexoate)	American Can Co. M&T Chems. Inc.	Rahway, N.J.
Dibutyltin iso-octyl thioglycolate	Ferro Corp. Ferro Chem. Div.	Bedford, Ohio
Dibutyltin maleate	American Can Co. M&T Chems. Inc.	Carrollton, Ky. Rahway, N.J.
	Anderson Dev. Co.	Adrian, Mich.
	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	New Brunswick, N.J.
Di-n-butyltin mercaptopropionate	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	Cincinnati, Ohio
Dibutyltin oxide	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
Di (n-octyl) bismaleate	American Can Co. M&T Chems. Inc.	Rahway, N.J.

Table 1. (Con't)

Chemical	Producer Company, subordination	 Location
Di (n-octyl) tin-S,S'-bis (iso-octylmercapto-acetate)	American Can Co. M&T Chems. Inc.	Rahway, N.J.
Di (N-octyl) tin oxide	American Can Co. M&T Chems. Inc.	Rahway, N.J.
Hexabutyltin	American Can Co. M&T Chems. Inc.	Carrollton, Ky. Rahway, N.J.
Hexamethyltin	American Can Co. M&T Chems. Inc.	Carrollton, Ky. Rahway, N.J.
Methyltin	American Can Co. M&T Chems. Inc.	Carrollton, Ky.
Organotin carboxylates	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	New Brunswick, N.J.
Organotin compounds (unspecified)	Cosan Chem. Corp.	Clifton, N.J.
Organotin maleates	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	New Brunswick, N.J.
Organotin mercaptides	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	New Brunswick, N.J.
Organotin mercapto acid esters	Cincinnati Milacron Inc. Cincinnati Milacron Chems. Inc.	New Brunswick, N.J.
Tetra-n-butyltin	American Can Co. M&T Chems. Inc.	Carrollton, Ky. Rahway, N.J.
Tetraphenyltin	American Can Co. M&T Chems. Inc.	Rahway, N.J.
Tributyltin acetate	American Can Co. M&T Chems. Inc.	Carrollton, Ky. Rahway, N.J.
Tri-n-butyltin chloride	American Can Co. M&T Chems. Inc.	Carrollton, Ky.

Table 1. (Con't)

	Producer	
Chemical	Company, subordination	Location
Tributyltin fluoride	American Can Co. M&T Chems. Inc.	Carrollton, Ky. Rahway, N.J.
Tri-n-butyltin hydride	Ventron Corp. Alfa Products Div.	Beverly, Mass.
Tributyltin oxide	American Can Co. M&T Chems. Inc.	Carrollton, Ky. Rahway, N.J.
	Filo Color and Chem. Corp.	Newark, N.J.
Tributyltin resinate	American Can Co. M&T Chems. Inc.	Carrollton, Ky. Rahway, N.J.
Tributyltin sulfide	American Can Co. M&T Chems. Inc.	Rahway, N.J.
Tri-n-butyltin salt (unspecified)	Royce Chem. Co.	East Rutherford, N.J.
	Woonsocket Color & Chem. Co.	Woonsocket, R.I.
Triphenyltin acetate	American Can Co. M&T Chems. Inc.	Rahway, N.J.
Triphenyltin chloride	American Can Co. M&T Chems. Inc.	Rahway, N.J.
Triphenyltin hydroxide	American Can Co. M&T Chems. Inc.	Rahway, N.J.

B. Costs

The United States is almost completely dependent on foreign countries for tin and tin-bearing minerals. Some semblance of order is established by a group called The International Tin Council, composed of representatives of the consuming and producing countries. At the regular quarterly meeting in July, 1972 the Council redetermined floor and ceiling prices for tin in the light of changes in exchange rates following the floating of the pound sterling. The U.S. Government subsidizes tin exploration up to 75 per cent of allowable costs. In 1972 the depletion allowance for tin remained at 22 per cent for domestic deposits and 14 per cent for foreign deposits.

The average New York price for delivery of Straits (Malaysian) tin in 1972 was approximately 399.125 cents per kilogram. This is a nominal increase over the 1971 price of about 368.927 cents per kilogram.(3)

C. Physical Properties

Physical properties of tin and the most important tin compounds are listed in Table 2.

Table 2.

Physical Properties (9)

Chemical	Specific Gravity	Melting Point °C	Boiling Point °C	Solubility Water g/100cc @ °C
Tin	7.28	231.88	2260	i
Stannic oxide	6.95	1127	subl 1800-1900	i
Stannous chloride	3.95	246	355	83.9^{0}, 269.8^{15}d
Stannic chloride	2.226 (liq)	-33	114.1	s
Stannic sulfate	--	>360	--	33^{25}
Dibutyltin diacetate	1.32	10	142-145	i
Tributyltin acetate	1.27	80-83	--	i
Tetra-n-butyltin	1.0572	<-70	145	-
Tetra-ethyltin	1.187	-112	181	i

II. PRODUCTION

A. Domestic Quantities

Domestic production of raw materials for primary tin in 1972 was less than 100 metric tons. Most of this came from Colorado as a byproduct of molybdenum mining. Some tin concentrates were also produced at dredging operations and as a byproduct of placer gold-mining operations in Alaska. The only primary tin smelter-refiner in the United States is the Texas City, Texas, plant of Gulf Chemical and Metallurgical Corporation. It uses imported tin concentrate from Bolivia together with reclaimed industrial residues as the base load. Five companies in eleven states were involved in detinning in 1972, making use of tin-plate scrap, spent chemicals, and tinning solutions. The United States leads in production of recycled or secondary tin. Individual company production figures are not available. Pertinent statistics of overall 1972 U.S. production are given in Table 3. As a rule the smelters are located close to the mining areas which are in foreign countries.(4)

Table 3.

U. S. Tin Statistics for 1972 (3)

Production or Source	Tin, metric tons
Tin-bearing ore	*
Smelter (primary tin)	4,060
Secondary tin	20,450
Exports	1,153
Imports for consumption	
Metal	53,200
Ore (tin content)	4,280

*Proprietary information

Domestic production of tin metal, chemicals, and alloys is uniquely related to secondary tin recovery as shown in Tables 4 and 5.(3)

Table 4.

Secondary Tin from Scrap at Detinning Plants, 1972

	Tin, metric tons
Tin recovered as:	
Metal	1,355
Chemicals (tin content)	608
Total	1,963

Table 5.

Recovery of Tin from Scrap, 1972 (exclusive of detinning plants)

Form of recovery	Metric tons
Bronze and brass	
From copper-base scrap	9,430
From lead- and tin-base scrap	74
Solder	5,300
Type metal	1,250
Babbitt	865
Antimonial lead	613
Chemical compounds	728
Misc. (foil, cable lead, terne metal, etc.)	8
Total	18,268

In 1972 tin from the strategic stockpile was not disposed of through commercial channels; however, 360 metric tons of tin were released for shipment to Turkey. The stockpile objective remained at 235,000 metric tons. At the end of 1973 there was an excess of about 19,000 metric tons on hand.(3)

B. Process

1. Primary Tin

The only tin smelter-refiner in the United States is in Texas City, Texas. It was built by the United States Government to supply emergency tin during World War II and operated under government contract. The ownership has since changed hands several times. The plant was originally designed to process high grade Bolivian tin concentrate into Grade A tin (minimum tin composition of 99.80 per cent) metal. The plant's limited success was blamed on the impurities in the Bolivian tin concentrate and the lack of an electrolytic refining plant. The plant has been modified to handle tin concentrates of varying grades. In 1972 the plant processed low grade tin concentrate from Bolivia and low-cost industrial residues. The plant process as described in a 1969 publication is schematically represented in Figure 1.(5) A recent change has been made which is supposed to greatly improve the plant's performance, but the exact nature of the change is considered proprietary information.

The plant performs the major function of: ore storage, roasting, leaching, smelting, refining (both thermal and electrolytic), casting, and shipment. The tin ore concentrates are delivered in 50 kg sacks to the Port of Texas City from the West Coast of South America. For the roasting operation the concentrates are crushed and fed into either the top hearths of two 6-hearth gas-fired furnaces or six 1.5-meter diameter X 15-meter long rotary kilns. The temperatures in the roasters change from 315 to 760 C and the retention time is about two hours. Most of the sulfur and some of the arsenic are removed in the roasting. Five per cent weight addition of sodium chloride is made for concentrates containing over 1 per cent lead. Ninety per cent of the lead is volatilized as the chloride. The next step is leaching. The dusts collected in balloon flues and electrostatic precipitators are subjected to leaching while the gas containing sulfur dioxide exits from a 80-meter high stack. The acid leaching system consists of twelve spherical pressure vessels 3.7 meters in diameter, with approximately 3,750 liters of preheated hydrochloric acid per 10 metric tons of concentrate. The leacher is revolved and heated with dry steam at 105 C for four hours and the material allowed to settle for one hour. The clear liquor is jetted into large thickeners for recovery of the five tin slimes.

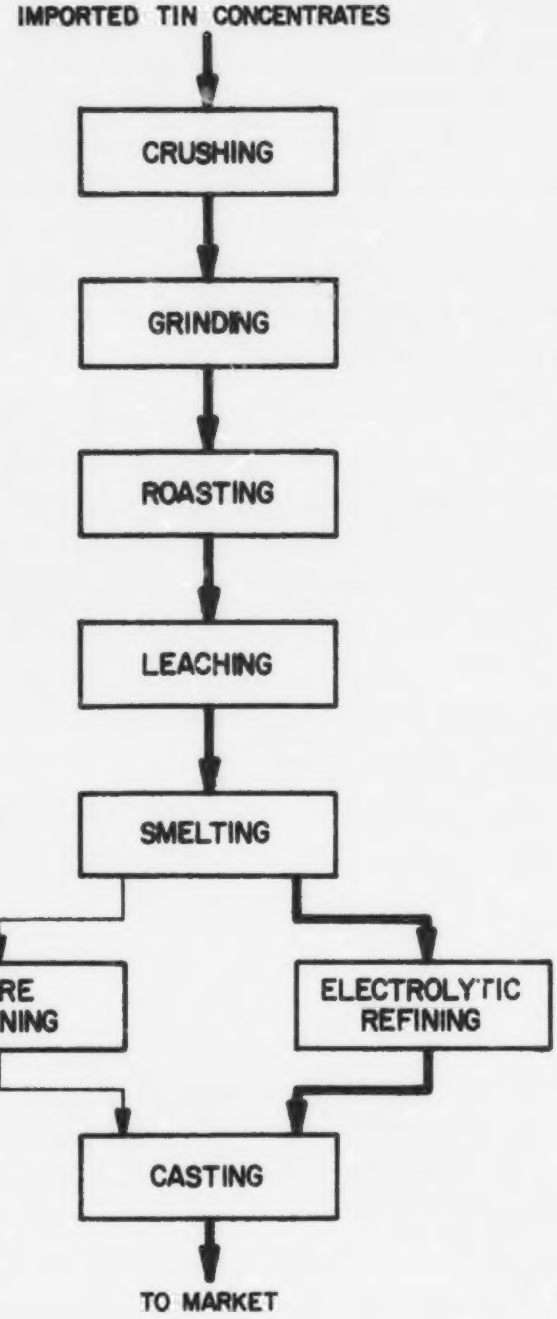
IMPORTED TIN CONCENTRATES
CRUSHING
GRINDING
ROASTING
LEACHING
SMELTING
FIRE REFINING
ELECTROLYTIC REFINING
CASTING
TO MARKET

Figure I

Texas City tin smelter - refiner

After the acid leach, the charge is washed with hot water to raise the pH to 5.0 and dried in a natural gas-heated rotary kiln. Most of the iron, lead, silver, copper, and bismuth are removed by the acid leach and hot water wash. Next smelting is performed in two gas-fired reverberatory furnaces. Depending on the type of charge, special treatment may be needed for iron and sulfur impurities. The tapped metal from the smelters is gravity-fed into brick-lined transfer floats and poured into cast iron kettles. "Dross" is skimmed off the kettles and added to the furnace, in addition to the regular charge, four hours or more before the tin is tapped.

The primary smelting furnace operates at 1400 C and produces a tin-rich slag (20 to 23 per cent tin) and crude tin metal. The slag is part of a secondary furnace charge, and the metal is removed to the drossing kettles. Since there is no practical way to remove lead and bismuth, purification is effected by electrorefining. The metal tapped from the furnaces is cast into anodes and scrap or unfinished anodes from the electrolytic cells added in the anode-casting process. The flue gases from both primary and secondary furnaces contain dust with from 48 to 68 per cent tin. This is pelletized and used as part of the primary furnace charge.

A high-melting iron-tin-arsenic-tungsten alloy is formed in the bottom furnace. These "furnace bottoms" are allowed to accumulate and removed only when the furnace is shutdown to be relined, about every two years.

Primary granulated furnace-rich slag and limestone charge the secondary smelting step and acts as a flux to keep the high melting slag a liquid. The end slag, which is discarded, contains less than one per cent tin, but represents the largest single loss of tin in the smelting process. The metal tapped from the secondary furnace is a tin-iron alloy called "hardhead" containing 45 to 75 per cent tin. This is granulated and used as part of the primary furnace charge. The next operation is electrolytic refining of the crude bullion to Grade A tin metal. The purity of the final product depends on the voltage and cathode current density; production is slowed if extremely high purity tin is made.

The unit at Texas City was developed by plant personnel as a result of laboratory and pilot plant investigations and is very flexible. Crude metal is cast into 180 kg anodes, pure tin metal plated out on 90 kg cathodes, while the impurities collect as anode slimes. The electrolytic plant has 80 concrete cells. The electrolyte feeds and discharges are arranged in multi-level fashion allowing use of gravity flow. As of 1969, the same electrolyte had been in the circuit for a period of almost six years. No bleed-off of electrolyte had been required, and a build-up of any impurity detrimental to the operation was not found. The electrolyte composition has been maintained by daily additions of sulfuric acid, phenolsulfonic acid, distilled water, animal glue, and cresylic acid. The sulfuric acid assures easy dissolution of anode tin and precipitation of lead. The organic additives are necessary to insure a firm and dense cathode deposit free from dendrites or trees.

The anodes are removed by overhead cranes in groups of 12 at least every two days for brushing in a special machine. The slimes or black mud brushed off contains the impurities of the crude metal. The anodes are washed, dried, and put aside for further processing.

The cathodes are removed every six days, washed and placed in hold kettles. The starter sheet, originally about 7 kg and now over 90 kg, is melted in the kettle. The finished liquid metal is pumped to the automatic continuous casting machine, where 40 kg pigs of electrolytic Grade A metal are formed. Part of the metal from the holding furnace is used to form starter sheets. A melting loss of less than five per cent takes place in the holding kettle. This dross is resmelted for recovery of Grade A tin metal.

Depending on prevailing market prices, the dried anode mud is either reduced to alloy, drossed, blended, and sold as solder or bearing metal alloy; or sold as is to bearing metal manufacturers. Any precious metal remaining in the slimes is recovered as an additional byproduct.(5)

The final product is shipped in 40 kg ingots by railroad car or barges. The tin ingots are normally double strapped in one metric ton-bundles of 27 ingots to a bundle prior to shipment.

2. Secondary Tin

a. Detinning

Detinning is the process of removing tin from tinplate scrap primarily to reclaim the basic steel. The tin may be recovered from the process as either a tin chemical or metal. Nearly all the scrap processed comes as new tin cans, although a small amount is from miscellaneous tin-plated steel. The largest potential source, used tin cans, is not widely exploited because of the high cost of collection. If the cans are not shredded, solution will be lost and dented cans provide poor tin recovery. The residual lead and tin from the soldered cans will create a poor grade of steel.(6)

(1) In the alkali-chemical detinning process (the most widely used) the tinplate scrap is treated with a hot solution of caustic soda in the presence of an oxidizing agent. The tin enters into solution as sodium stannate, leaving the steel which is then washed and pressed into bales. The tin may be recovered from the stannate solution as metal, crystals of sodium stannate, or tin oxide.(6)

(2) The alkaline-electrolytic process uses the sodium stannate solution described above as a plating bath. This has the advantages of low processing costs and produces a high purity metal.(6)

b. Other Secondary Tin Recovery

Alloy scrap containing tin is handled by secondary smelters as part of their production of primary metals and alloys. Lead refineries, for example, accept solder, tin drosses, babbitt, and type metal. This type of scrap is remelted, impurities such as iron, copper, antimony, and zinc removed, and the scrap returned to the market as a binary or ternary alloy. The dross from the clean-up of scrap metal is returned to the primary refining process.

Iron-tin and copper-tin can be largely removed from liquid solder by lowering the temperature to just above the melting point and withdrawing the sludge from the bottom of the pot with a perforated paddle; another technique is to pass the liquid under pressure through an asbestos filter in a specially designed vessel. Impurities can also be partly removed from solder by heating it to just above 183 C. At this temperature the eutectic alloy, 63 per cent tin - 37 per cent lead, melts and flows away leaving the higher melting impurities.

Copper refineries will accept scrap bronze metal. Tin-bronze scrap is largely free from objectionable impurities and is recovered by simply remelting or adding the scrap to new metal. Bronze scrap, if highly contaminated with iron, nickel, zinc, lead, or precious metals, is channeled through the primary smelting and electrorefining processes.

3. Stannic Oxide

Stannic oxide is made by two quite different processes. In one, the so-called "dry" process, tin metal is oxidized in a furnace, using air or oxygen. The product, stannic oxide, is recovered in a dry dust collector and packaged for sale. There are no wastes from this process. The 12,500 to 16,700 liters water per metric ton of product is used for cooling and does not come into contact with the metal.

The "wet" process now in use involves scrap as the source of tin and uses about 185,300 liters of municipal water per metric ton of product stannic oxide. This appears as waste discharge which goes through a settling tank to remove muds and then to the municipal sewer. Future plans call for this plant to use pure tin instead of scrap which should simplify various chemical pretreatments and reduce the raw waste load. Various sludges which accumulate in the wet process are sold for their tin content.(7)

III. USES

A. Tin

Tin is the most expensive of the common metals so it is only used when no other common metal will do the job satisfactorily. In many cases the amount of tin used is small enough not to affect the cost of the manufactured product. In tin-plated steel, for example, a few millionths of a centimeter of "nontoxic" tin adds strength, corrosion-resistance, and appearance.(4) The product becomes printable, formable, solderable, and laquerable. The consumption of tin in the United States by finished product is given in Table 6. The values show very little change from 1971.(3) Table 7 shows the uses of tin and its compounds.

B. Substitute Materials

The largest amount of tin used is tinplate for containers. In the late 1960's manufacturers worried about the domestic supply of tin and began using steel and aluminum in place of tinplate for cans. These substitute metals did not prove to be as economical as expected. The greatest potential source of tin is from the recovery of tin from used tinplate. At the present time this is an uneconomical operation, but several factors may combine to change the picture in the future, not the least of which is the problem of solid waste disposal. A technique has been developed to separate aluminum scrap from the magnetic metal scrap. This may make tin recovery from used cans much cheaper. Not to be overlooked is the balance between the supply and demand for tin. One estimate is that the U.S. tin requirement for 1977 will be five per cent higher than the amount needed in 1970. 1977 tinplate usage is expected to be lower than the 1970 amount.(8)

Table 6.

U.S. Consumption of Tin, 1972
(metric tons of contained tin)(3)

Finished Product	Primary Tin	Secondary Tin	Total
Alloys (miscellaneous)	475	448	923
Babbitt	2,241	904	3,145
Bar tin	792	118	910
Bronze and brass	3,144	6,651	9,795
Chemicals	2,501	1,593	4,094
Collapsible tubes and foil	803	16	819
Pipe and tubing	*	*	*
Solder	17,166	5,030	22,196
Terne metal	195	41	236
Tinning	2,573	80	2,653
Tin plate	21,407	—	21,407
Tin powder	1,168	—	1,168
Type metal	105	749	854
White metal	1,604	140	1,744
Other	186	5	191
Total	54,262	15,775	70,135

*Withheld as proprietary

Table 7.

Table of Uses of Tin and Tin Compounds

Compound	Use	Purpose	Comments
Elemental Tin	Coating tin plate and tin alloys		Ingots are cast into anodes this use
	Bottle cap liners Electrical condensers Gun charges Food wrapping		Uses tin foil
	Distilled water and carbonated beverages	Extruded tin pipe and tin-lined brass pipes used for shipping containers	
		Sheet tin used to line distilled water storage tanks	
	Powder metallurgy		Uses tin powder
	Float-glass process	Molten tin used as a surface on which the molten glass is allowed to float and solidify	Results in smooth surface, making costly polishing and grinding unnecessary
	Other	Special pharmaceutical products Food pastes Artists paint	Uses collapsible tubes, extruded from slugs of tin
Tin Oxides	Vitreous enamel opacifier		
	Marble polishing		
	Intermediate for other chemicals		
Tin Chloride	Electroplating baths		
	Catalyst	Used for silvering mirrors	
	Chemical reducing agent		
	Electrical conducting glass		
	Food additive	Improves taste	
	Perfume stablizer		
	Hardening glass surface		
	Organic chemical intermediate	Used in manufacture of organo-tin compounds	

Table 7. (Con't)

Compound	Use	Purpose	Comments
Tin Sulfate	Electroplating baths Liquor finishing wire		
Tin Fluoride and Tin Pyrophosphate	Toothpaste additive	Source of fluoride	
Tin Bromide	Heavy metal separations		
Tin Fluoborate	Electroplating baths		
Tin Octoate	Catalyst	Used in polyurethane foam manufacture	Organo-tin compound
Monobutyltins	Plastics	Used as stabilizer	Organo-tin compound
Dibutyltins	Plastics	Used as stabilizer for polyvinylchloride plastics	Organo-tin compound
	Veterinary uses		Organo-tin compound
	Catalysts	Used in polymerization	
	Chemical intermediate		
	Rodent repellant		
Tributyltins	Biocides		Organo-tin compound
	Industrial fungicide		
	Insecticides		
	Disinfectants		
	Paint additive	Provides a protective coating	
	Food preservative		
	Navigation aides (Buoys)	Provides a protective rubber coating	
Triphenyltins	Agricultural	Fungicide and insecticide	

IV CURRENT PRACTICE

A. Transportation and Handling Reguations

The only tin compound in the "List of Explosives and Other Dangerous Articles" is tin tetrachloride, anhydrous. Other tin compounds are considered poisonous and their shipping containers must be so labeled. Tin tetrachloride is classified as a corrosive liquid and requires a white label. Rail express is limited to carrying no more than 1 liter in one outside container.(9)

V. ENVIRONMENTAL CONTAMINATION

A. From Use

Most tin containers are used to store food. A study of the tin content of condensed milk samples was made. Where the product was not over four weeks old, the tin content was at most 40 ppm, and rose inappreciably for an additional five months. In storage experiments lasting more than two years, however, the tin content rose to 160 ppm in exceptional cases. While there are no reports of poisoning by the tin present in condensed milk, it has been suggested that the date of filling be stated on the cans so that only new cans be used for infant feeding.(10)

B. From Production

The only tin smelter-refiner in operation in the United States uses the process described schematically by Figure 2. Dust losses occur during the crushing of the feed ore, the roasting step, leaching, drying, and smelting in the reverberatory furnaces. The gas and particulates from these processes go through electrostatic precipitators and then are discharged through a 80-meter high stack. The recovered particulates are returned to the process. The waste slag, which is inert and insoluble, is used for land fill on the property. All liquid wastes are neutralized, clarified, and discharged "through approved effluent points as provided in state regulations".(11) Some modifications have been made recently to improve the operations, but details are not available.

C. Entry of Tin into the Environment

The major source of tin entering the environment is tin plate used to coat steel cans for containment of food and other materials. Since little of this tin is reclaimed, essentially all of the roughly 20,000 metric tons of tin per year utilized in this manner may be assumed to enter the environment. Some wastes also arise from the use of tin in solder.

Contribution from tin-bearing rocks and soils may be considered much smaller than the above value. Because of the relatively high value of tin, smelting and other processing wastes are minimal, and much of the tin used for purposes other than tin plate and solder is reclaimed. Waste hazards from manufacture and use of the toxic organo-tin compounds do not appear generally significant because the waste quantities are small and the compounds are minimally soluble in water.

Perhaps the most significant aspect of tin plate solid waste is the availability of the tin, much of which would be recoverable under economic conditions more favorable than at present.

VI. MONITORING AND ANALYSIS

A. Monitoring

The Environmental Protection Agency, state and local agencies conduct air sampling activities to obtain information about the quality of the air in the United States. Tin was one of twelve metals checked in suspended particulate matter. The last published detailed survey, based on sampling during 1968-1969, showed tin concentrations in urban and nonurban regions during the various seasons. The detectable concentrations of tin were 0.001 micrograms per cubic meter for urban samples and 0.0003 for nonurban areas. The tin concentration was decidedly higher in urban areas with the highest concentrations occurring during the colder months. The highest maximum values reported were 0.120 micrograms per cubic meter for Jersey City and 0.100 for Philadelphia.(12)

B. Analytical Methods

1. Identification of Tin-bearing Mineral

Cassiterite (stannic oxide) is the only tin-bearing mineral of importance. It is recognized in the field by its high density (7.01 grams per cubic centimeter), low solubility in acid and alkaline solutions, and extreme hardness.(4)

2. Analysis of Tin Concentrate

a. A fire assay method is used to analyze the tin concentrations at the smelters. After preliminary digestion with nitric and hydrochloric acids, the sample of concentrate is mixed with sodium cyanide in a clay or porcelain crucible and heated in a muffle furnace at red heat for 20-25 minutes. The tin oxide is reduced to metal and weighed.(4)

b. Tin concentrates can be put into solution by fusion with a mixture of sodium carbonate and sodium peroxide in a nickel crucible at red heat. This is followed by leaching the fused salts with water, acidifying with hydrochloric acid, and reduction by digestion with a coil of nickel sheet. The solution is cooled in a protective atmosphere of carbon dioxide, and titrated with a standard potassium iodate-iodide solution with starch as an indicator.

c. The analysis of tin in concentrates as well as in metals containing over 75 per cent tin requires a special procedure. A weighed sample is dissolved in hydrochloric acid, reduced with nickel, and cooled in a carbon dioxide atmosphere. A calculated weight of pure potassium iodate (dried at 100 C) and an excess of potassium iodide are dissolved in water and added to the reduced solution to oxidize 96 to 98 per cent of the stannous chloride present. The reaction is completed by titration with 0.1N potassium iodate-potassium iodide solution to a blue color using starch as an indicator.(4)

3. Analysis and Detection of Organo-Tin Compounds

Organo-tin compounds are highly toxic, so this method of detection in the air was developed. The measured air is passed through a mixture of 30 to 35 per cent hydrogen peroxide and concentrated sulfuric acid. This is followed by colorimetric determination of the stannic ion in the form of a yellow-orange compound by the standard series method or with a photoelectrocolorimeter. The sensitivity is 0.1 microgram per sample. Interference of ferric ion or antimony (3+) is eliminated by the addition of ascorbic acid.(13)

VII. CHEMICAL REACTIVITY

A. Environmental-Associated Reactions

1. Tin does not react directly with nitrogen or carbon dioxide; however, sulfur dioxide when moist attacks tin. The metal is normally covered with a thin protective film of stannic oxide which thickens as the temperature is raised.(4)

2. A new development is a catalytic system using stannic oxide co-precipitated with vanadate for the oxidation of carbon monoxide. This could be of importance in treating auto exhaust gases.(14)

B. Use-Associated Reactions

1. In the absence of oxygen, the high overpotential of tin causes a film of hydrogen to be retained on the surface so that attack by acids is retarded.(4)

2. A reversal of potential of the iron-tin couple occurs when tin-coated steel (tinplate) is in contact with acid solution in the absence of air. The tin coating acts as the anode and is slowly attacked instead of the steel. This unique property is the keystone of the canning industry. Organic acids such as citric, lactic, and oxalic acids attack tin slowly in the presence of air or other oxidizing environments. Nonaqueous organic solvents, lubricating oils, and gasoline have little effect on tin.(4)

VIII. BIOLOGY

A. Absorption and Excretion

Daily tin consumption in humans may range from 1 mg in diets composed chiefly of fresh, unprocessed foods to 38 mg in diets including many canned foods and fish.(18) Ingested tin is absorbed very poorly by the small intestine. In a variety of mammals, less than 10 per cent of the oral intake of tin is absorbed, even when sodium stannous tartrate, a soluble salt, is the tin source.(19) Therefore, the feces are the major mode of tin excretion. Systemic tin is excreted in the urine, and small amounts are excreted in the bile.(20) Table 8 shows the typical distribution of ingested tin compared with the distribution of that amount excreted.

Table 8.
Tin Balance in Man
(15)

	Average Daily intake (mg)			Average Daily output (mg)	
Food	4.0	(1-40)	Feces	3.98	(1-40)
H_2O	0.0	(0-0.03)	Urine	0.023	(0-0.4)
Air	0.003	(0-0.007)			
Total	4.003		Total	4.003	

Average daily amounts of tin excreted in the urine of man range from 0.13 to 0.33 µg/kg body weight. Fecal tin excretion ranges from 0.11 to 0.45 µg/kg body weight per day.(18,20,21) Intravenously injected tin is only slowly excreted by the kidneys.(20) No tin was detected in the urine of rats fed 10 ml of a solution containing 1200 ppm tin as tin citrate. The feces contained 96 per cent of the administered tin dose.(23) The lack of tin in the urine is probably due to lack of absorption. The tin citrate was 65 per cent tin (IV) and only 35 per cent tin (II) citrate. Since rats cannot absorb tin (IV),(24) only very minute amounts, if any, could be present in the urine.

Organotin compounds are also absorbed by the small intestine. Table 9 shows blood levels of tin three hours after single oral dosage of various tin compounds to rabbits.(20)

B. Transport and Distribution

Absorbed tin is carried to all parts of the body by the blood. Inorganic tin does not cross the blood-brain barrier, but organic tin does.(25) Since no tin was found in stillborn infants, tin apparently does not cross the placental barrier.(18)

Tin rapidly leaves the vascular system and is deposited in various parts of the body. Tin (II) is deposited primarily in the soft tissues (muscle, skin, extracellular fluid) and organs. Tin (IV) is retained in the bones, soft tissues and organs.(20)

The tin distribution throughout the body as reported by several sources is summarized in Table 10. The brain contains no tin; the bones contain the highest levels. Tin accumulates in the lungs with advancing age.(15)

The tissue distribution of tin in rats given 5 ppm tin as tin (II) ions in their drinking water is shown in Table 11. Some accumulation is noted in all organs but the kidney. The distribution of tin in the rat is different from distribution in man.

Organic tin compounds are also accumulated by the body tissues. Blood levels of tin after oral doses of some organotins appear in Table 9. After intravenous injection of tetraethyltin (11) or triethyltin (12) in the rat, the highest tin concentrations appear in the blood (see Table 12). In the rabbit, hamster, and guinea pig, however, the highest levels of tin occur in the liver. The bile of the guinea pig and hamster contained copious amounts of tin. The high tin level in rat blood is due to the efficient binding of tin to rat hemoglobin (molar ratio 2:1). Tin binding to hemoglobins of other species and other proteins is much poorer or nonexistent.(27) The subcellular distribution of tin in liver, kidney, and brain of rats appears in Table 13. The highest tin concentration in the liver appears in the supernatant fraction, but the nuclear fraction has the most tin in the brain.(27)

Table 9.

Blood Levels of Tin Three Hours After Oral Doses of Organotin Compounds

Compound	Single Oral Dose (mg/kg)	Tin in Blood (ppm)
Dibutyltin diacetate	110	90
Dibutyltin di-(2-ethylhexanoate)	200	130
Tributyltin acetate	300	140
Tetrabutyltin	500	200

Table 10.

Tin Levels in Tissues of Man
(14)

Tissue	Tin Content (ppm, Wet Weight) (1a)	(1b)	(2)	(7)	(8)
whole blood	-	-	0.14	0.22-0.40	-
red blood cells	-	-	-	0.26-0.64	-
plasma	-	-	-	0.04-0.10	-
brain	0	-	0.0	-	0
muscle	0.1	-	0.11	-	3.3
heart	0.2	-	0.22	-	0.07
liver	-	0.35-1.0	0.60	-	1.01
kidney	0.2	0.23-0.76	0.20	-	-
spleen	0.2	-	0.22	-	-
intestine	0.2	-	0.16	-	-
lung	0	0.44-1.20	0.45	-	-
aorta	-	0.22-0.94	-	-	-
long bone	0.8	-	0.80	-	8.6
rib	-	-	0.50	-	-
stomach	-	-	0.50	-	-

Table 11.

Effects of Tin in the Diet on Levels of Tin in Tissues of Adult Rats (2-3 years old) Chronically Fed 5 ppm Tin in the Diet (26)

Tissue	Tin Concentration (ppm) Controls	Tin Concentration (ppm) Tin-Fed
Kidney	0.31	0.17
Liver	0.11	0.35
Heart	0.59	0.93
Lung	0.14	0.54
Spleen	0.96	1.88

Table 12.

Levels of Triethyltin in Animal Tissues Four Hours after Injection of Tin-113-Triethyltin (10 mg/kg) (Animals Perfused before Tissue Samples Collected)
(27)

	Triethyltin (Nanomoles/g Wet Weight)		
Tissue	Rat	Guinea pig	Hamster
Liver	103.0	275.0	124.0
Kidney	52.7	78.5	31.4
Muscle	16.2	17.8	26.0
Brain			
Cerebellum	22.4	28.1	25.2
Brain stem	22.0		
Cerebrum (half)	22.4	-	-
Cortex	21.2	-	-
Remainder of brain	21.6	24.8	24.6
Spinal cord	20.7	24.4	23.1
Fat	30.3	11.2	48.7
Bile	-	57.0	404.0
Blood	224.0	8.3	7.7

Table 13.

Subcellular Distribution of Tin-113-Triethyltin in the Liver, Kidney, and Brain of the Rat. (Results of one experiment)

	Triethyltin (nanomoles/mg protein)		
Subcellular Fraction	Liver	Kidney	Brain
Total homogenate	0.71	0.44	0.27
Nuclear and debris	0.59	0.41	0.42
Heavy mitochondrial	0.30	0.31	0.28
Light mitochondrial	0.62	0.39	0.26
Microsomal	0.65	0.51	0.28
Supernatant	1.01	0.43	0.24

Tin is not consistently found in plants. Lichens are apparently tin accumulators. The lichens growing on silicic rock contained 72.4 ± 4.7 ppm tin. On ultrabasic rock, the tin content was 37.0 ± 8.0 ppm.(15) Mosses contained 24 ± 8.6 and 18 ± 5.5 ppm tin, respectively, when growing on the same type of rocks. In Russia, plants growing in areas with tin deposits have been reported to contain high levels of tin.(28) Herbage in Scotland has been found to contain 0.3 to 0.4 ppm tin on a dry basis.(15) Triphenyltin acetate, an agricultural fungicide, was not taken up by plants.(29)

C. Growth and Nutrition

The essentiality of tin for man has not been established. Tin is apparently essential for normal growth in rats, but its function is unknown.(30) The aphid, Macrospinum rosae, utilizes tin as judged by the occurrence of alate forms in the presence of the element.(21) No nutritional requirement in plants has been established. Traces of tin have been reported to stimulate root growth in sunflowers, and growth in grains and legumes.(15)

D. Biochemistry

1. Effects of Inorganic Tin

Stannous chloride feeding in stock feeds at levels of 0.30 and 1.00 per cent significantly reduced growth in male and female rats. Hemoglobin content of the blood was reduced after four weeks of either diet in both males and females. Serum alkaline phosphatase activity was significantly reduced in rats fed on a 0.3 per cent stannous chloride diet for 13 weeks, but serum glutamate-oxaloacetate transaminase, serum glutamate-pyruvate transaminase, and bilirubin levels were unaffected.(31)

2. Production of Edema

A visible increase in the water content of the central nervous system occurs after triethyltin (TET) treatment. The levels of total nucleic acid, total lipid, phospholipid and cholesterol per unit dry weight were unchanged.(32)

The effect of TET (20ppm in the diet) on the water content, electrolyte distribution and the kinetics of radioactive sodium, chloride and sucrose uptake of cerebral cortex and skeletal muscle were studied. In the TET-treated animals, water content of the cortex was increased by 1.2 per cent, but muscle water was not altered. Potassium levels were not changed in brain cortex and skeletal muscle; sodium and chloride increased in both of these tissues. TET-induced cerebral edema in rats, characterized by a reduction in extracellular space and increase in glial cell volume, is apparently due to an increased permeability of the glial cell membrane to sodium and chloride, resulting in an influx of both ions.(33)

The lipid composition of rat brain myelin was examined in chronic TET-induced edema. A noticeable decrease in the amount of stainable myelin occurred, which was apparently due to a change in myelin composition. Decreases in proteolipid protein and galactolipids were consistent with the changes in myelin properties.(34)

3. Effects on Energy Metabolism

Total oxygen consumption is depressed by 3 mg/kg TET in the rat, but tissue oxygen tension was adequate for normal metabolic functioning. Slices of brain cortex, brain white matter, and spinal cord metabolizing glucose were more sensitive to TET than were other tissues. Under aerobic conditions, lactate increased, pyruvate fell and glucose uptake rose. TET depressed both glucose uptake and lactate formation under anaerobic conditions.(32) Similar results were observed in brain homogenates. TET does not inhibit lactate dehydrogenase.(32)

Trialkyltin compounds affect the oxidative activity of isolated liver mitochondria. Trialkyltin homologues up to tri-n-octyltin inhibit mitochondrial oxidation. At low concentrations, trimethyl- and triethyltin stimulated mitochondrial oxidation. Oxidative phosphorylation was also inhibited by trialkyltins. Triethyltin is the most potent inhibitor known, inhibiting oxidative phosphorylation at concentrations of 10^{-7} molar.(35)

The actions of the trialkyltins on mitochondrial metabolism are believed to be caused by the activation of a latent adenosine triphosphatase. Only trimethyl- and triethyltin have a pronounced effect, hence the stimulation of oxidative activity at low concentrations. At high concentrations, inhibition is probably a result of damage to the mitochondria. Triethyltin produces large amplitude swelling of mitochondria *in vitro*.(36) The trialkyltin compounds, except tri-n-octyltin, inhibited the activation of adenosine triphosphatase by 2, 4-dinitrophenol.(37)

The binding of trimethyltin and triethyltin to rat liver mitochondria was determined. One binding site had the same characteristics as the inhibition of oxidative phosphorylation. Since ultrasonication rapidly destroyed the site, the intact mitochondrial membrane was necessary for the effect of the trialkyltins.(38)

4. Miscellaneous Effects

The effect of TET on incorporation of radioactive amino acids into rat tissue protein is quite curious. No change in incorporation occurred within fifteen minutes, but pancreatic protein incorporation was 50 per cent of control after two hours, and liver incorporation was raised 50 per cent after 24 hours. No changes in kidney or brain were observed.(32)

In isolated rat intestine, 10^{-6} to 10^{-5} molar TET inhibited transport of water and glucose. Glucose utilization was inhibited by 2×10^{-4} molar TET. TET was 100 times less effective on inhibiting transport in the intact rat.(32)

TET reduced the permeability of the blood brain barrier to inorganic phosphorus-32 but had only a slight effect on the distribution of dyes. The distribution of radio-phosphorus within the acid-soluble fractions of the brain was the same as controls except that NAD contained relatively less radioactivity. There was also a lower radioactivity in the lipid and residual phosphate fractions. In the liver, the relative labelling of the lipid fraction was again reduced, but a relative increase in the residual fraction occurred.(32)

Single oral doses of 300 mg/kg tributyltin acetate or 500 mg tetrabutyltin to rabbits produced significant increases in serum glutamate pyruvate transaminase 144 hours after the dose.(39)

Fatal doses of triethyltin given to the rat caused a moderate hyperglycaemia secondary to the liberation of adrenalin by the adrenal medulla. Serum nonprotein nitrogen was elevated, and urinary porphyrin excretion greatly reduced. *In vitro* a 25 per cent inhibition of horse serum pseudocholinesterase. was achieved by $1.4 \times 10^{-3}M$ triethyltin.(32)

The pharmacological effects of tetraethyltin are similar to those of TET.(40) Tetraethyltin is converted to triethyltin in the liver. The microsomal plus soluble fractions exhibited the most activity *in vitro.* Kidney preparations could perform a small amount of conversion but other tissues such as brain were inactive. Oxygen, nicotinamide, divalent magnesium, and NADPH were required *in vitro.*(40) Female rats converted tetraethyltin tin at a slower rate than males.(40) No evidence suggests that di- or trialkyltin compounds are metabolically altered.

E. Microorganisms

Tributyltin chloride depressed respiration in mitochondria prepared from the mycelia of Aspergillus oryzae. The P/O ration was lowered.(41)

IX. ENVIRONMENTAL EFFECTS

A. Environmental Content, Transportation, and Contamination

The presence of tin in most of the foods ingested by humans is shown in Table 14. Generalizations about the most likely sources of dietary tin are difficult, but oily sea foods preserved in tin cans appear to be the most likely source. Lacquering tin cans reduces the amount of tin which can leach into the contents.

Drinking water is a possible source of tin for humans. Tin was found in only three out of 59 samples from 15 major North American rivers. Many salts of tin are insoluble, and factory effluents probably contribute little tin to rivers. Tin levels in municipal waters have been difficult to reliably obtain. The U.S. Public Health Service found tin ranging in concentration from 0.8 to 30 ppb in 32 of 175 finished municipal waters.

Sizeable amounts of tin occur in the atmospheres of American cities, especially where industry is located. Amounts of tin from 0.003 to 0.3 µg/m^3 were found in 60.6% of 754 samples taken from 22 cities. Suburban areas had the least. Assuming a respiratory volume of 20 m^3/day, 740 µg of tin in the lungs per day, and deposition of one-eighth of the inspired tin, air containing 0.015 µg/m^3 would not account for human pulmonary levels until age 55.(15)

Plastic products stabilized with organotin compounds represent another possible source of tin contamination. Leaching of low levels of di-n-octyl (1-^{14}C)-tin-2-ethyl-n-hexyl dithioglycolate from polyvinyl chloride into edible oils and fat stimulants was demonstrated.(16) The toxic leachable substance in PVC catheters for humans has been shown to be an organotin compound.(17)

Cigarettes contained 1.58 ppm tin. "20 per cent Superphosphate" from Florida contained 3.24 ppm tin.(15)

1. Environmental transport

Tin removed from the soil by plants may be ingested by herbivores. Since less than 10 per cent of the tin taken in is absorbed, most would be excreted, presumably unchanged, in the feces. The action of soil bacteria on tin is not known.

Table 14
(15)

Tin in Fresh and Processed Food and Tissues (wet weight)

Sample	µg/g	µg/100 cal	Source
Condiments			
Garlic bud	0.3	------	Chain store
Cloves, packaged	0.47	------	Chain store
Vegetables			
Peas, split, green, dried, bulk	1.92	64	Chain store
Peas, split, dried, packaged	8.50	281	Chain store
Peas, fresh	1.06	166	Home garden
Peas, fresh, fertilized	1.69	264	Home garden with phosphate
Beans, Navy, dried	5.80	191	Chain store
Beans, string, fresh	0.28	187	Home garden
Potato, raw	0.97	111	Vermont
Turnip, raw	0.11	61	Home garden
Turnip greens	0.07	64	Home garden
Radishes	0.38	253	Home garden
Radish leaves	0.0	------	Home garden
Parsnips	1.02	203	Institute garden
Swiss Chard	0.23	88	Institute garden
Lettuce, Iceberg	0.07	61	Home garden
Spinach	1.23	473	Institute garden
Spinach	0.89	342	Home garden

Table 14
(15) (cont.)

Tin in Fresh and Processed Food and Tissues (wet weight)

Sample	µg/g	µg/100 cal	Source
Spinach, fresh, packaged	6.47	2488	Troy, N.Y.
Cabbage, raw	0.40	95	Institute garden
Kale	0.86	430	Home garden
Asparagus, fresh	9.07	5039	Local 'organically' grown
Rhubarb, fresh	1.29	2150	Institute garden
Rhubarb, fresh	1.88	3133	Local 'organically' grown
Mushrooms, fresh	1.08	1543	Chain store
Mushrooms, in glass	0.72	1029	Chain store
Soil, dry weight	161.94	------	Home garden
Soil, dry weight	32.71	------	Institute garden
Animal tissues			
Lamb liver	0.32	23	Vermont
Lamb chop	1.36	72	Local market
Beef, ground, lean	2.76	153	Local market
Beef, roast	0.51	23	Local market
Beef, brisket	1.10	28	Local market
Beef and fat, ground	3.44	90	Local market
Beef, bone marrow, forelimb	0.42	------	Chain store

Table 14
(15) (cont.)

Tin in Fresh and Processed Food and Tissues (wet weight)

Sample	µg/g	µg/100 cal	Source
Pork, lean chop	0.84	26	Local market
Chicken Breast, frozen	1.73	92	Local market
Gelatin, packaged	3.50	135	Chain store
Lobster, claw meat	0.60	50	Maine
Oysters, frozen	1.36	276	Cape Cod
Halibut steak	1.21	121	Chain store
Codfish steak,1	3.67	459	Chain store
Codfish steak,2	0.49	60	Chain store
Greysole fillet	3.21	382	Newfoundland
Bloaters, smoked	4.30	169	Chain store
Cereals and grains			
Rye, winter	1.9	57	Fallow ground
Soil, field, dry weight	37.10	------	Where rye grown
Rye flour from seed	0.0	------	Feed store
Barley	0.65	18	Feed store
Corn meal	0.11	3	Chicago
Corn, fresh on cob	0.12	4	Local store
Macaroni	4.76	418	Chain store
Wheat flour	0.47	14	Japan
Wheat flour	0.0	------	U.S.
Wheat seed	0.0	------	Feed store
Wheat bread	2.48	100	Chain store

Table 14
(15) (cont.)

Tin in Fresh and Processed Food and Tissues (wet weight)

Sample	µg/g	µg/100 cal	Source
Oats, seed	2.28	------	Feed store
Oatmeal, packaged	2.63	66	Chain store
Rice, packaged	0.28	8	Chain store
Dairy products			
Milk, dry skim, packaged	0.96	29	Nationally distribute
Milk, raw, bulk cans tinned	0.68	100	Local farm
Milk, from udder into polyethylene	0.19	29	Local farm
Cheese, tinfoil wrapped	0.32	8	France
Eggs, chicken	0.91	57	Local farm
Miscellaneous			
Peach	0.0	------	Chain store
Tea, packaged, bags	2.28	------	Ceylon
Rat diet (rye, corn oil, dry skim milk)	0.28	7	
Laboratory dog chow	1.0	25	Spectrographic method
Dog meal	0.8	20	Spectrographic method
Rabbit pellets	2.0	50	Spectrographic method
Rat diet, commercial	0.8	20	Spectrographic method
20% Superphosphate	3.24	------	Florida
Phosphate rock	4.24	------	Tennessee

Table 14
(15) (cont.)

Tin in Fresh and Processed Food and Tissues (wet weight)

Sample	µg/g	µg/100 cal	Source
20% Superphosphate	4.06	------	Yugoslavia
Cigarettes	1.58	------	National brand
Urine, human	0.0	------	Normal female
In Coated cans			
Condensed tomato soup	7.35	1470	Chain store
Green beans, French	2.84	4055	Chain store
Whole beets	3.38	768	Chain store
Carrots, dietetic	6.45	3071	Cleveland, Ohio
Apricots, sweetened	4.99	818	Cleveland, Ohio
Spinach, dietetic	11.82	4546	Cleveland, Ohio
Asparagus	8.96	4922	California
In Uncoated cans			
Kipper snacks	61.88	3094	Norway
Anchovies	129.31	5851	Portugal
Sardines	18.65	634	Morocco
Sardines	1.57	53	Portugal
Corn oil, bulk	4.10	45	National brand
Coffee, ground	3.65	------	National brand
Molasses	4.15	161	Louisiana
Chile powder	3.9	------	Chain store
Thyme, ground	4.8	------	Chain store
Cloves, whole	7.26	------	Chain store

B. Bioaccumulation

Animals fed a diet containing tin accumulate the element in their body tissues. Differences in tin content of human tissues are evident when individuals from different geographical locations are compared. Table 15 shows shows the tin found in geographical groups around the world. Tin was quite low in Africans, and was not detected in well over half of the organs sampled. The lungs of all groups contained the highest concentrations of tin, perhaps indicating the importance of airborne sources of tin. Additional support of this idea is the consistently high tin levels and frequency of detection of tin in tissues of persons from the heavily industrialized United States.(15)

Laboratory animals chronically fed or injected with tin compounds have higher tissue levels than controls. Foragers ingesting plants containing significant amounts of tin may themselves develop elevated tin levels.

Tin levels in plants may not reflect differences in soil levels of tin, but differences in species ability to accumulate tin. Lower plants, such as lichens and moss tend to contain higher levels of tin than higher plants. Table 16 presents tin levels found in some species of forest plants and wildlife in Vermont. Despite an abundance of tin in the soil, the plants vary greatly in their accumulation of tin (15) Table 17 lists tin levels in plants grown on different types of soils containing tin.(15)

The concentration of tin in sea water is about 3 ppb. Tin has been found in marine algae, but not in zooplankton, bacteria, flowering plants, protozoa, sponges, coelenterates, echinoderms or most fish. Small amounts have been reported in a marine worm, an oyster, and a dogfish. The presence of tin in phosphate fertilizers, which come from marine phosphorites, suggests that marine animals in the Pleistocene absorbed tin from the sea.(15)

Table 15
(15)

Geographical Distribution of Tin in Kidney, Liver and Lung of Man (p.p.m. ash)

	No. of Samples	% Present	Mean	Range	Median
Kidney					
United States	161	97	30	<5-480	20
Switzerland	9	33	5	<5-17	< 5
Africa	53	19	5	<5-30	< 5
Middle East	43	42	8	<5-55	< 5
Far East	57	40	11	<5-110	< 5
Liver					
United States	163	96	35	<5-300	24
Switzerland	9	78	6	<5-20	Tc
Africa	49	25	4	<5-20	< 5
Middle East	44	55	11	<5-140	Tc
Far East	54	41	10	<5-74	< 5
Lung					
United States	159	98	69	<5-920	39
Switzerland	7	100	37	23-62	28
Africa	50	60	10	<5-40	Tc
Middle East	45	91	33	<5-200	17
Far East	57	93	65	<5-1200	29

Note: Tc=trace, or barely detectable.
Mean and median values were obtained by assigning a value of one half the least detectable amount to those cases where tin was not detected.

Table 16
(15)

Tin in Animal Tissues and Vegetation from Vermont

Sample	µg/g (wet weight)
Animal tissues	
Ruffed grouse liver	0.50
Muskrat liver	0.33
Woodchuck livers (3)	1.77
Beaver heart	7.28
Deer liver	0.82
Deer kidney	2.20
Deer kidney	1.65
Deer heart	0.0
Deer kidneys (4)	0.0
Red fox liver	3.50
Vegetation	
Pine, white, needles *Pinus strobus*	0.37
Spruce, red, needles *Picea rubra*	0.0
Soft wood chips	0.70
Elm, section, 40 yr old	1.70
Elm, section, 80 yr old	1.39
Clover, *Trifolium pratense*	0.38
Wild blueberries	0.14
Poplar leaves, *Populus tremuloides*	0.0

Table 16
(15) (cont.)
Tin in Animal Tissues and Vegetation from Vermont

Sample	ug/g (wet weight)
Maple leaves, *Acer saccharum*	0.18
Birch leaves, *Betula alba*	0.0
Oak leaves, *Quercus rubra*	0.0
Alfalfa, *Medicago sativum*	2.92
Fern, suburban, fronds	0.69
Peonies, pink flowers	0.0
Barberries	1.06
Mountain ash, berries	0.10
Soil, forest	-----

Note: Trees and blueberries were situated in a remote hilltop forest; the elm, fern and mountain ash were suburban. The clover and alflafa came from a pasture 5 miles from a town.

Table 17
(15)

Tin in Plants

Species	No. of Samples	Positive Samples No.	Positive Samples %	Soil*	Content (p.p.m. ash) Mean + S.E.M.	Content (p.p.m. ash) Range
Lichens	59	55	93.2	S	72 ± 4.7	<10-100
				U	37 ± 8.0	10- 60
Mosses	16	10	62.5	S	24 ± 8.6	<10- 60
				U	18 ± 5.5	<10- 30
				C	12 ± 9.0	<10- 30
Ferns, fronds	93	20	21.5	S	3.2 ± 0.21	<10- 10
Conifers	83	9	10.8	S	3.2 ± 0.15	<10- 10
Deciduous trees and shrubs	117	2	1.7			<10- 30
Dwarf shrubs	48	5	10.4	U	6.0 ± 3.0	<10- 30
Herbs	403	7	1.7	U	3.8 ± 0.80	<10- 30
Grasses	30	1	3.3		300	----
Soil	94	13	13.8	S	4.5 ± 0.50	<10- 30
	23	0	0	U	---	<10
	17	3	17.6	C	4.6 ± 1.6	<10- 30
Rock	180	8	4.4	S	3.8 ± 0.56	<10-100
	50	0	0	U	---	<10
	34	0	0	C	---	<10

*S=silicic, U=ultrabasic, C=calcareous. These terms describe the character of the underlying rocks from which the soil was formed.

X. TOXICITY

A. Humans

1. Occupational Exposure

(a) Inorganic Tin. Exposure to the dust or fume of tin causes a benign pneumoconiosis-stannosis. Workmen involved in bagging tin oxide, tending furnaces in which metallic tin is burnt to tin oxide, or processing tin ores may receive substantial exposures. Small dense shadows appear in lung x-rays. The cases of stannosis were not disabled, and lung function tests were within normal limits, as were the blood and urine tests.

(b) Organic Tin. Brief contact with organic tin compounds may cause acute skin burns. Tributyl and dibutyl compounds are especially caustic. Lesions consisted of reddening and swelling of the hair follicles two to three hours after exposure. The reaction became more intense over the next eight hours, and minute pustules over the follicular openings formed during the second day. The skin between the hair follicles was little affected. Only faint erythema and scaling remained after a week.

Subacute lesions are characterized by itching and may affect the skin of the lower abdomen, thighs, and groin of workmen handling these compounds through clothing contamination. A faint erythematous eruption develops, but disappears rapidly upon removal from contact.(42)

In five young persons employed in a chemical laboratory, acute organotin intoxications occurred. In all cases, headaches and nausea, with visual defects were reported. Electroencephalogram showed general disturbances and dysrhythmia, as well as occipital foci of short waves.(43)

2. Epidemiological

(a) Inorganic Tin. Colloidal metallic tin and tin arsenate were tested as treatments for typhoid and staphylococcal infections. Little therapeutic effect was observed, but no toxic reactions were reported either.(42)

An orange juice and apple juice containing 250 to 385 ppm tin were under suspicion as the causes of an outbreak of food poisoning in Kuwait in 1967. Experiments with animals indicated that tin levels (as tin (IV) citrate) must be at least 1400 ppm before toxic signs appear, and that toxicity is due to the local irritation of the mucous membrane of the digestive tract. The major toxic effect was emesis.(23)

(b) Organotin. Attempted therapy of bacterial infections by organic tin compounds has led to disastrous results. In France, a preparation called "Stalinon" was used for the treatment of various infections. The active ingredient was diethyltin diiodide, but high amounts of impurities as monoethyl and triethyltin produced 217 cases of poisoning, 100 of which were fatal. Triethyltin is ten times as toxic to rats as diethyltin and contributed up to ten per cent of the theoretical weight of diethyltin.

Poisoning symptoms appeared after a latent period of about four days, beginning with a severe persistent headache. Vomiting, vertigo, abdominal pain, and urine retention followed. Paralysis occurred in severe cases; death, preceded by convulsions or coma, was due to cardiac or respiratory failure. Edema of the white matter of the brain was the most significant lesion at necropsy.(42)

B. Animals

1. Acute Toxicity

The doses of tin compounds required for the development of symptoms of acute toxicity have been compiled in Table 18. In general, inorganic tin compounds are not as toxic as organic tin compounds containing small alkyl groups. Pathology of the liver and spleen is evident in poisoning by inorganic tin.

The increasing order of toxicity of the organotin derivatives for a series of homologues appears to be monoalkyltin < dialkyltin < trialkyltin = tetraalkyltin. The larger homologues are usually less toxic than the lower ones. Long chain fatty acid salts of organotins are less toxic than the inorganic salts.

Table 18.

Toxic Doses of Tin Compounds

Compound	Mode of Administration	Animal	Toxicity	Dose (mg/kg)	Reference
A. INORGANIC					
tin (IV) chloride	intraperitoneal	mouse	LD_{50}	21	(46)
tin (II) chloride	intraperitoneal	mouse	LD_{50}	41	(46)
	intravenous	dog	LD_{Lo}	20-50	(46)
	oral	rats	LD_{50}	700	(47)
	oral	mouse	LD_{50}	1200	(47)
tin (II), disodium tartrate	intravenous	rat	LD	20	(52)
	subcutaneous	rabbit	LD	25	(52)
tin (IV) iodide	intravenous	rat	LD_{Lo}	200	(52)
B. ORGANIC					
tin, bis(tributyl)-oxide	oral	rat	LD_{Lo}	175	(46)
tin, dibutyl-,diacetate	oral	rabbit	LD_{50}	109	(46)
tin, dibutyl-,dichloride	peroral	rabbit	LD_{50}	125	(48)
	intraperitoneal	rat	LD_{Lo}	7.5	(46)
	intravenous	rat	LD_{50}	5	(46)
	oral	rabbit	LD_{Lo}	50	(46)
	peroral	mouse	LD_{50}	35.0	(48)
	peroral	rat		182	(48)
	peroral	guinea pig	LD_{50}	190	(48)
tin, dibutyl-,di-(2-ethylhexoate)	oral	rat	LD_{50}	200	(46)
tin, dibutyl-, oxide	intraperitoneal	rat	LD_{50}	40	(46)
	intraperitoneal	rat	LD_{50}	39.9	(49)
tin, diethyl-, dichloride	intravenous	rat	LD_{50}	25	(46)
	oral	rat	LD	40	(50)

Table 18. (Con't)

Compound	Mode of Administration	Animal	Toxicity	Dose (mg/kg)	Reference
B. ORGANIC (con't)					
tin, diethyl-, diiodide	intraperitoneal	rat	LD	15	(50)
	oral	rat	LD	100	(50)
	intraperitoneal	rat	LD	26	(50)
tin, di-2-ethylhexyl-, dichloride	intravenous	rat	LD_{50}	5	(46)
tin, diisopropyl-, dichloride	intravenous	rat	LD_{50}	15	(46)
tin, dimethyl-, dichloride	intravenous	rat	LD_{50}	40	(46)
tin, dioctyl-, bis (2-ethyl hexyl maleate)	oral	mouse	LD_{50}	2700	(51)
tin, dioctyl-, bis (butyl maleate)	oral	mouse	LD_{50}	3750	(51)
tin, dioctyl-, bis (2-ethylhexyl thioglycolate)	oral	rat	LD_{50}	2100	(46)
tin, dioctyl-, maleate	oral	mouse	LD_{50}	2250	(51)
tin, dioctyl-, mercaptide	oral	rat	LD_{50}	750	(46)
tin, dipropyl-, dichloride	intravenous	rat	LD_{50}	7	(46)
tin, monolthyl-, trichloride	intraperitoneal	rat	LD	200	(50)
tin, mono-n-butyl-, trichloride	oral	rat	LD_{50}	1400	(45)
mono-n-butyl thiotin acid	oral	rat		15,000-20,000	(45)
tinox (fentin)	oral	rat	LD_{50}	84	(46)
tin, tetrabutyl-	oral	rat	LD_{50}	6000	(46)
tin, tetraethyl-	peroral	rabbit	LD_{50}	7.0	(48)
	oral	rat	LD_{50}	16	(46)
	peroral	mouse	LD_{50}	40.0	(48)
	peroral	guinea pig	LD_{50}	40.0	(48)

Table 18.
(con't)

Compound	Mode of Administration	Animal	Toxicity	Dose (mg/kg)	Reference
B. ORGANIC (con't)					
tin, tributyl-, acetate	oral	rabbit	LD_{50}	99	(46)
tin, tributyl-, linoleate	oral	rat	LD_{50}	1305	(46)
tin, tributyl-, neodecanoate	oral	rat	LD_{50}	658	(46)
tin, tributyl-, oxide	intraperitoneal	rat	LD_{50}	7.21	(49)
tin, triethyl-, acetate	intraperitoneal	rat	LD_{50}	4	(46)
tin, triethyl-, chloride	intraperitoneal	rat	LD_{50}	5	(46)
tin, triethyl-, sulfate	intraperitoneal	rat	LD_{50}	5.7	(46)
	intraperitoneal	rat	LD	10	(50)
	intraperitoneal	guinea pig	LD_{50}	3	(46)
	oral	rat	LD	10	(50)
tin, trimethyl-, sulfate	oral	rat	LD	30	(50)
	intraperitoneal	rat	LD	16	(50)
tin, triphenyl-, acetate	oral	rat	LD_{50}	429	(46)
	intraperitoneal	rat	LD_{50}	8.5	(46)
	oral	mouse	LD_{50}	81.3	(46)
	intraperitoneal	mouse	LD_{50}	719	(46)
	oral	guinea pig	LD_{50}	23.5	(46)
	intraperitoneal	guinea pig	LD_{50}	3.7	(46)
	intraperitoneal	chicken	LD_{50}	10	(46)
tin, triphenyl-, thiocyanate	oral	rat	LD_{Lo}	500	(46)
tin, dibutyl-, dilaurate	intraperitoneal	rat	LD	85	(50)

Monoalkyltin poisoning is evidenced by hemorrhaging of the gastric mucosa, steatosis of the liver and spleen.(45) Dialkyltins affect the liver and bile duct. Severe lesions are produced in the bile duct, and death results from hepatic damage or peritonitis.(18) Trialkyltins affect the central nervous system, causing progressive weakness, convulsions and paralysis. Severe edema of the white matter of the brain is the major pathological finding. Tetraalkyltins are converted to trialkylins in the liver, and thus the toxic effects are the same.(18) In most cases, alkyl tin compounds cause severe burns when applied to the skin. Dibutyltin compounds apparently are absorbed through the skin as well, since biliary lesions also occur.

2. Chronic Toxicity

Inorganic Tin

Oral dosages of powdered tin have proven completely harmless to rats. Rats fed 5 ppm tin as stannous chloride grew as well as controls, but female rats fed tin had a reduced life span.(26) No innate toxicity of tin was observed in male or female mice.(44) In rats fed diets containing different amounts of tin for 4 or 13 weeks, no adverse effects appeared in rats ingesting tin (II) sulfide or oleate or tin (II) or tin (IV) oxides. Severe growth retardation, decreased food efficiency, slight anemia, and slight histological changes in the liver were observed in rats receiving 0.3 per cent or more tin (II) chloride, orthophosphate, sulfate, oxalate, and tartrate. Dietary iron protected against the tin-induced anemia.(47)

Tin hydride is highly toxic to animals when administered by inhalation. More toxic than arsine, its effects were mainly on the central nervous system.(42)

Organic Tin. The lower trialkyltin compounds, especially triethyltin, exert a specific effect on the central nervous system, producing cerebral edema. Dialkyl tin compounds do not exert this effect, but are severe skin irritants and have an inflammatory action on the bile ducts.

An oral dose of 50 mg tin as dibutyltin chloride per kg body weight in the rat caused congestion and inflammation of the lower bile duct. Repeated dosage caused more extensive bile duct damage and necrotic changes in the liver. The highest harmless level in food for rats is 20 ppm.

Severe skin damage and typical bile duct injury resulted from skin applications of 10 mg dibutyltin per kg over a period of 72 days. The dioctyl and higher homologs had no toxic effects on the skin of rats, guinea pigs, or rabbits.(42)

Trialkyl and tetraalkyl tin salts produce the same biological effects because the tetraethyl compounds are first demethylated by the liver to the trialkyl homologue. Chronic toxicity (following 20 ppm triethyltin oxide orally) was characterized by weakness of the hind legs in rats. Increasing concentrations produced tremors and weight loss.(42)

C. Invertebrates

1. Insects

Many organotin compounds have been used as insecticides. Listed below are some of these organotins which have proven effective against the insect species following them. The minimum lethal dose, if known, follows the insect species.

Tributytin oxide - Helothis vivescens, 0.2 μg/larva(57), Stegobium paniceum, 0.1 per cent(57), Tincola bisselliella, 8 per cent(81), carpet beetl

Triphenyltin hydroxide - Heliothis vivescens, > 10 μg/larva(57)

Triphenyltin chloride - Cellosobrochus chinensis(57), Musca domestica, 0.25 μg/gm(89), Daphnia longspina, 0.25 ppm(90), Libelloid larva, 0.25 ppm(90)

Triphenyltin acetate - Heliothis vivescens > μg/larva(57), Musca domestica 0.25 μg/gm(89), Antigastra catalavnalis(91), Pseudodaletia separata(91), Prodenia litura(93)(97), Spodoptera littoralis(92), Hymenia facialis, 0.2 to 0.4 per cent(93)

Tricyclohexyltin hydroxide - Phytophagous mites(94), Tetranychos urticae(95), Panonychus citri(96), Tetranychos pacificus (96)

Triethyltin hydroxide - Musca domestica, 0.4 μg/fly(63)

Trimethyltin hydroxide - Heliothis zea, 0.2 μg/larva(57)

Trimethyltin acetate - Heliothis zea; 0.2 μg/larva(57), Heliothis vivescens, 0.2 μg/larva(57)

Hexamethyltin - Noctuidae (flies)(57)

The effectiveness of various organotins against clothes moth larvae (Tincola biselliella) is shown in Table 19. Significant weight losses are produced by some compounds which are not lethal.

2. Molluscs

Organotin compounds have molluscidal properties as illustrated in Table 20. The lethal concentrations of various organotins for various snails are shown.

3. Worms

Organotins have been employed as vermicides against various types of parasitic worms, particularly tapeworms (cestodes). The antihelminthic activity of different organic tin compounds against specific species is shown in Table 21.

4. Plants

The lower alkyltin acetates are quite toxic to plants. Triethyltin acetate and tripropyltin acetate are toxic to the broad bean, Vicia faba. Triphenyltin acetate is less toxic, but still hazardous; it is very toxic to rice. Trivinyltin chloride is a nonselective herbicide. An 0.5% solution kills charlock (Sinapis arvensis).(57)

Table 19.

Per Cent Mortality and Weight Loss of Clothes Moth Larvae (Tincola bisselliella) treated with Organotin Compounds, one per cent by Weight (55)

Compound	Mortality	Weight Loss Grams	Weight Loss as % of Control
Tributyltin oxide	100	0	0
Triphenyltin thiophenoxidl	76	0.0019	3.3
Triphenyltin chloride	67	0.0010	1.7
Triphenyltin acetate	61	0.0019	3.3
Triphenyltin bromide	53	.0007	1.2
N-(Triphenyltin)-p-toluene sulphonamide	52	.0020	3.4
Triphenyltin isocyanate	5	.0007	1.2
Triphenyltin hydroxide	50	0.0014	2.4
Triphenyltin isothiocyanate	50	0.0005	0.9
Triphenyltin iodide	46	0.0015	2.6
Triphenyltin oxide	31	.0014	2.4
Diphenytin dichloride	26	.0032	5.5
Triphenyltin benzoate	12	.0026	4.5
Triphenyltin sulphide	3	.0098	17
Hexaphenylditin	0	0.0292	50
Tetraphenyltin	0	0.0596	102

Table 20.

Lethal Concentrations of Organotin Compounds for Various Species of Molluscs

Compound	Concentration	Mollusc	Reference
Triphenytin chloride	0.5 ppm	*Australorbus glabratus*	(56)
	0.5 ppm	*Bulinus contortus*	(59) (62)
	1.0 ppm	*Limnea stagnalis*	(59) (62)
	1	*Biomphalaria glabrata*	(57)
Tributyltin oxide	0.075 ppm	Aquatic snails	(58)
	0.015 to 0.04	*Bulinus tisuncatus*	(59)
	0.015 to 0.04	*Biomphalaria glabrata*	(59)
	0.015 ppm	*Biomphalaria camerounensis*	(59)
	0.015 ppm	*Australorbis glabratus*	(59)
	0.015 ppm	*Bulinus contortus*	(59)
	3 µg/l	Aquatic snails	(59)
Triphenyltin acetate	3 µg/l	Aquatic snails	(60)
	0.5 mg/l	*Biomphalaria glabrata*	(61)
	0.5 mg/l	*Bulinus contortus*	(57)
Tributyltin acetate	0.2 to 0.3 ppm	*Biomphalaria glabrata*	(57)
	3 µg/l	Aquatic snails	(60)
	0.3 ppm	*Australorbus glabratus*	(62)
	0.3 ppm	*Bulinus contortus*	(62)
Tripropytin oxide	0.2 to 0.3 mg/l	*Biomphalaria glabrata*	(57)
Tributyltin oleate	3µg/l	Aquatic snails	(60)
Tributyltin benzoate	3µg/l	Aquatic snails	(60)
Tributyltin laurate	3µg/l	Aquatic snails	(60)
Tributyltin chloride	3µg/l	Aquatic snails	(60)
Tri-p-tolytin acetate	--	*Biomphalaria glabrata*	(61)
Tricyclopentylmethyltin acetate	--	*Biomphalaria glabrata*	(61)

Table 21.

Antihelminthic Action of Organotins

Tin Compound	Species of Worm	Lethal Dose	Reference
dibutyltin dichloride	Hymenolysis fraterna (cestode)	--	(63)
dibutyltin dilaurate	Railletina cesticillus (cestode)	75 mg/kg	(57,64)
	Eimeria tenella	--	(57)
	Eimeria necatrix	--	(57)
	Ascardia galli	--	(57)
	Moniezia benedeni (cestode)	--	(57)
	Dipylidium caninum	300 mg/kg	(65)
	Hymenolepis carioca (cestode)	—	(66)
	Choanotaenia infundibulum (cestode)	--	(66)
	Raillietina tetragona (cestode)	--	(66)
	Raillietina echinobothrida (cestode)	--	(66)
	Cotognia digonopora (cestode)	—	(66)
dibutyltin oxide	Crepidostomum farionis (trematode)	150 mg/kg	(67)
	Eubothrium crassum (cestode)	500 mg/kg	(68)
dibutyltin maleate	Hymenolepis carioca (cestode)	—	(66)
	Cotugnia digonopora (cestode)	—	(66)
	Choanotaenia infundibulum (cestode)	—	(66)
	Raillientia cesticillus (cestode)	—	(66)
	Raillientia echinobothrida (cestode)	—	(66)
	Raillientia tetragona (cestode)	—	(66)
dibutyltin disterate	Dipylidium caninum	300-400 mg/kg	(65)
diethyltin dichloride	Rhabditis macrocerca	1 per cent	(57)
diphenyltin dichloride	Raillientina cesticillus (cestode)	--	(66,69)
	Raillientina tetragona (cestode)	—	(66,69)
	Raillientina echinobothrida (cestode)	--	(66,69)
	Hymenolepis carioca (cestode)	—	(66,69)

Table 21. (Con't)

Tin Compound	Species of Worm	Lethal Dose	Reference
diphenyltin oxide	Choanotaenia infundibulum (cestode)	--	(66)
Tin arsenate	Moniezia benediti (cestode)	--	(70,71)
	Moniezia expansa (cestode)	--	(70,72)
	Ascaribia styphlocerca (cestode)	--	(70)
	Stilesia globipunctata (cestode)	--	(70)
	Avitellin centripunctata (cestode)	--	(70)
Triethyltin hydroxide	Rhabditis macrocerca	1 per cent	(73)

D. Microorganisms

1. Fungi

Both the type of alkyl group and the kind of salt affect the antifungal properties of organotin compounds. Table 22 shows the concentrations of different salts of triethyltin required to inhibit the growth of four different fungi. The influence of the type of alkyl groups or groups on antifungal activity appears in Table 23. No generalizations for toxicity can be made based on this data.

Table 24 lists some organotin compounds found to be effective against fungal infestations of plants and the organisms against which they are active. Excessive levels of organotins can be phytotoxic, also.

2. Algae

Trimethyltin hydroxide, trimethyltin acetate, tribenzyltin hydroxide and tribenzyltin chloride are very toxic to green algae at concentrations as low as 0.2 mg/l. *Scenedesmus quadricauda*, *Chlorella vulgaris* and *Asteromonas gracilis* were investigated.(74)

3. Bacteria

Tributylacetoxystannane had a pronounced antibacterial effect on cocci of 29 strains of gram-positive and gram-negative bacteria.(98) Trialkyltin compounds are the most active towards gram-positive bacteria such as *Bacillus subtilis*, *Micobacterium phlei*, and *Streptococcus lactis*.(57) Triethyltin acetate and tripropyltin acetate are the most active triaklyltins against gram-negative bacteria.(57) Tetraalkyltins exhibited increasing bactericidal activity with increasing chain length from ethyl to butyl groups. In the trialkyltin bromides, the ethyl and propyl compounds had little activity, the butyl compound was the most toxic and the amyl not very toxic.(89)

The inhibitory effect of 0.03 per cent aqueous-alcohol solutions of PVC stabilizers on the respiration of *Pseudomonas aeruginosa* was 20 per cent greater with dibutyltin 2-ethylhexylmaleate than with Mellite-131.(90)

Table 22.

Antifungal Activity of Different Salts of Triethyltin (55)

Compound	Antifungal Activity (ppm for complete inhibition growth) Fungus: Botrytis allii	Penicillium italicum	Aspergillus niger	Rhizopus nigricans
triethyltin hydroxide	0.2	5	0.5	0.5
triethyltin chloride	0.5	2	5	2
triethyltin bromide	0.5	2	1	1
triethyltin iodide	0.5	1	5	2
Bis(triethyltin) sulfide	0.2	1	1	1
Bis(triethyltin) sulfate	0.2	0.2	5	5
triethyltin acetate	1	2	5	2
triethyltin caproate	1	5	2	2
triethyltin laurate	0.2	0.2	5	5
triethyltin benzoate	2	10	5	5
Bis(thriethyltin) malonate	0.5	5	2	1
Bis(triethyltin) maleate	0.5	5	0.5	0.5
triethyltin pheonoxide	0.5	1	2	1
triethyl p-toluenesueforanide	1	5	2	5
triethyl methanesulforanide	0.5	5	2	2
P-(triethyltin sulfonyl)toluene	1	5	2	2
N-(triethyltin) saccharin	1	10	2	2
N-(triethyltin) phthalimide	0.2	5	1	2
truethyl p-mitre phenoxide	0.5	2	2	2

Table 23.

The Influence of the Alkyl Group on the Antifungal Properties of Some Trialkyltin Acetates (55)

Antifungal Activity (ppm for complete inhibition of growth)

			Fungus		
Compounds	# of alkyl carbon atoms	Botrytis allii	Penicillium italicum	Aspergillus niger	Rhizopus nigricans
$(X = OCO\ H_3)$					
$(CH_3)_3SNOCO\ H_3$	3	20	20	200	200
$(C_2H_5)_3SNX$	6	1	2	2	2
$(CH_3)(C_4H_9)SNX$	6	1	2	5	5
$(C_2H_5)_2(C_4H_9)SNX$	8	0.1	1	0.5	0.5
$(C_3H_7)_3SNX$	9	0.1	0.1	1	1
$(iso\text{-}C_3H_7)_3SNX$	9	0.1	0.1	1	0.5
$(CH_3)_2(C_8H_{17})SNX$	10	0.5	0.5	0.2	2
$(C_2H_5)_2(C_6H_{13})SNX$	10	0.5	0.5	0.1	0.1
$(C_4H_9)_3SNX$	12	0.1	0.1	0.5	0.5
$(C_2H_5)_2(C_8H_{17})SNX$	12	0.02	0.5	0.1	> 5
$(C_5H_{11})_2(C_2H_5)SNX$	12	0.2	1	1	0.5
$(CH_3)_2(C_{12}H_{25})SNX$	14	0.2	1	0.2	10
$(C_5H_{11})_3SNX$	15	0.2	5	5	10
$(C_2H_5)_2(C_{12}H_{25})SNX$	16	0.2	5	0.5	50
$(C_6H_{13})_3SNX$	18	1	10	20	100
$(C_8H_{17})_3\ SNX$	24	>100	>100	>100	>100
$(C_4C_{10}\text{-}C_6H_{11})_3SNX$	18	0.5	0.5	5	20
$(C_6H_5)_3SNX$	18	2	1	0.5	10

Table 24.

Organotin Compounds Used in the Treatment of Fungal Infections of Some Crop Plants

Compound	Plant Disease	Pathogen	Reference
Triphenyltin acetate	potato blight	*Phytophchora infestans*	(75,76)
	celery spot	*Septoria apii*	(76)
	sugar beet spot	*Cercospoca beticola*	(77,76)
Triphenyltin hydroxide	celery spot	*Septoria apii*	(78)
	sugar beet spot	*Cercospora beticola*	(79,78)
	potato blight	*Phytophthora infestans*	(78)
	peanut blight		(78)
	stem-end blight	*Carya illinoensis*	(80)
	pecan scab	*Fusicladium effusum*	(81)
	rice blast	*Piricularia oryzae*	(82)
Triphenyltin chloride	celery spot	*Septoria apii*	(76)
	potato blight	*Phytophthora infestans*	(76)
	sugar beet spot	*Cercospora beticola*	(76)
Tributyltin oxide	wood rot	*Coniophora olivacea*	(82)
	wood rot	*Poria monticola*	(82)
	wood rot	*Fomes lividus*	(82)
Triphenyl(phenylthio)	tin potato blight	*Phytophthora infestans*	(83)
Triphenyl(p-chloro-phenylthio) tin	potato blight	*Phytophthora infestans*	(83)
A-36*	potato blight	*Phytophthora infestans*	(84)
	celery spot	*Septoria apii*	(84)
	sugar beet spot	*Cercospora beticola*	(84)
Tripropyltin acetate	wood rot	*Coniophora olivacea*	(88)
Tributyltin acetate	wood rot	*Poria monticola*	(88)

*[Decafentin = (Dicyclotriphenylphosphonium-bromochlorotriphenylstannate]

E. Results of Personal Contacts with Medical Personnel

A total of 74 toxicologists and medical examiners throughout the United States were contacted by telephone or letter with regard to their professional acquaintance with incidences of accidental poisoning by tin or tin compounds. Of the 31 responses, one was positive. This involved a non-fatal case of poisoning attributed to ingestion of tin in food from a corroded tin can. Poisoning of other family members was not known by the respondent.

XI. CURRENT REGULATIONS

The "agreed" limit on tin content in foods is 300 mg/kg in the U.S. and 286 ppm (mg/kg) in the United Kingdom.(4)

The only tin compound in the "List of Explosives and Other Dangerous Articles" is tin tetrachloride, anhydrous. Tin tetrachloride is classed as a corrosive liquid and requires a "white" label. The maximum quantity which can be shipped in one outside container by rail express is one liter.(9)

Other tin compounds except for tin oxide are considered toxic (see XII) and must be so labeled.

XII. STANDARDS

A. Inorganic Compounds except SnH_4 and SnO_2

TLV - 2 mg/m^3 as Sn (99)

The above limit is recommended in the interest of preventing stannosis. Tin salts in the blood stream are highly toxic, producing paralysis and other neurologic damage. (99)

B. Organotin Compounds

TLV - 0.1 mg/m^3 as Sn

Organotin-compounds are numerous and vary widely in their toxic reaction and effects. In view of this, actual experience with specific organotin compounds is of vital importance. Since many of the organic tin compounds have not yet been fully investigated, the TLV indicated above is recommended for the entire organotin class of compounds. (99)

XIII. SUMMARY AND CONCLUSIONS

A. Summary

The United States is dependent on foreign countries for tin and tin minerals. It is not by accident but by design that the U.S. leads the rest of the world in production of recycled or secondary tin. Tin is the most expensive of the common metals; and, as a consequence of price and availability, tin is not used where suitable substitutes are available.

Typically, the amount of tin used in most applications is so small as to have little effect on the cost of the product. The selective and limited use of tin has been pursued since World War II, and tin is one of the few materials for which there is a strategic stockpile maintained by the General Services Administration. The largest uses are for tin plate and solder.

There is almost no contamination of the environment from processing of tin or its compounds. The recovery and reprocessing of tin wastes is a large factor in this. The one significant source of environmental contamination which involves tin is scrap tin cans and tin plate in general. Disposal of these wastes instead of metal recovery is strictly due to economic considerations.

Some local conditions do or can occur which constitute health hazards to workers in the tin processing and user industries, but these are quite limited and the effects are not acute. One definite source of contamination of the environment with tin is from food stored in tin cans. Although serious health problems attributed to this source appear to be unusual, the ingestion by humans of tin from this source is continually under surveillance. An unofficial limit of tin in foods of 300 mg/kg has been set.

As a generalization, inorganic tin compounds are relatively nontoxic. Inorganic tin compounds are poorly absorbed by the intestine, and most of ingested tin is excreted in the feces. Tin is essential for normal growth in rats. Some tin may be absorbed through the lungs, but inhaled tin oxide particles produce only benign lesions in the lung tissue. Tin does not appear to be a carcinogen, teratogen or allergen.

Organic tin compounds may be absorbed through the intestine and skin and are quite toxic, depending upon the type of organic groups present, and the degree of substitution on the tin. Trialkyltins are the most toxic to mammals, producing cerebral edema and hepatic degeneration. Tetraalkyltins are converted to trialkyltins in the liver; thus the toxicity symptoms are the same. Dialkyltins are excreted in the bile, and fatal peritonitis or liver damage may occur. Monoalkyltins produce gastric irritation. Organotins have proven effective as insecticides, molluscides, vermicides, and fungicides.

Tin accumulation by plants varies with the species. Lichens and mosses contain relatively high levels of tin. Phytotoxicity can result from excessive applications, but the actions of tin on plants are not clearly established.

B. Conclusions

The following conclusions are based on the information presented in this report:

(1) Tin as an environmental contaminant appears to be essentially harmless.

(2) Man is continually ingesting tin in canned foods, but most of this tin is quickly eliminated and detrimental effects are rare.

(3) The major source of tin entering the environment in this country is through disposal of tin plate (mostly tin cans). When exposed to the elements this tin rather quickly enters the soil and surface water. When the economics of reclaiming tin from tin plate becomes favorable, much of the tin now entering the environment will be recyclyed instead.

C. Recommendations

There are no recommendations for further study of environmental effects of tin and its compounds at this time.

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GLOSSARY

Abomasum - The true digestive stomach of ruminante. Also called 4th stomach.

Acetic Acid - An aqualor solution containing 36-37% CH_3COOH.

Acetylation - Chemical introduction of an acetyl radical (CH_3-CO-) into the molecular structure of an organic compound.

Acetylcholine - $(CH_3)_3N(OH)CH_2CH_2-OCOCH_3$. Neurotransmitter released from parasympathetic postganglionic and all preganglionic nerve terminals.

Acne Vulgaris - The common type of acne occurring in sexually maturing and mature individuals, and related to hormonal imbalance.

Action Potential - Changes in electric potential at the surface of a nerve or muscle at the moment of their excitation.

Activated Sludge - Treatment of water with a sludge containing microbial decomposers to reduce the organic matter in the water.

Active Transport - The movement of biochemicals against a concentration gradient. It requires energy.

Acute Toxicity - Rapid onset, a short course and pronounced symptoms of a poison.

Adenocarcinoma - One originating in glandular or ductal epithelium and tending to produce acimic structures.

Adipose - Fat, fatlike.

Adjuvnant - A material administered with and enhancing the action of a drug or antigenic substance.

ADP - Adenosine diphosphate. The result of a removal of one P group from ATP.

Adrenalin - Trade-mark for epinephrine.

Adrenal Cortex - The peripheral portion of the adrenal gland.

Aerobic Respiration - Requiring air or free oxygen in order to live.

Agar - Any of various culture mediums containing agar-agar, a dried mucilaginous extract obtained from seaweeds.

Albumin - One of a group of protein substances, the chief constituents of animal tissue.

Alcohol dehydrogenase - An enzyme of yeast, capable of reversibly oxidizing ethanol to acetaldehyde.

GLOSSARY

Alkali Disease - Selenium poisoning disease in sheep and cattle which results from ingestion of selenium indicator plants.

Alkaline - Containing more hydroxyl than hydrogen ions.

Allantoicase - Enzyme which converts allantoic acid to urea and glyoxylic acid.

Alpha-2-globaline - A fraction of serum globulin.

Alveolus - An air cell of the lung.

Amavadin - Vanadium-containing compound synthesized by Amanita muscaria.

Ameloblast - An enamel cell; helps in the formation of dental enamel.

2-Amino-6-selenopurine - a selenium derivative of uric acid.

Aminopyrine Demethylase - A liver detoxifying enzyme.

Anaerobic - Absence of molecular oxygen.

Anaphylaxis - A state of increased susceptibility or hypersensitivity.

Anaplastic Carcinoma - A malignant epithelial tumor, characterized by reversion of form of a cell or cells toward the embryonal, with increased capacity for multiplication.

Anemia - A significant reduction below normal in the number of erythrocytes, hemoglobin concentration, and the volume of packed red cells/100 c.c. of blood, resulting in a decrease in the oxygen-carrying capacity of a given volume of blood.

Anorexia - Absence of appetite.

Anthocyanin - Any of a class of glycosides comprising the soluble coloring matter of blue, red and violet flowers.

Antigen - Any substance which stimulates the production of antibodies or reacts with them.

Antioxidant - Any substance which delays the process of oxidation.

Aorta - The large vessel arising from the left ventricle.

GLOSSARY

Arginase - Enzyme which catalyzes the conversion of the amino acid arginine plus water to ornithine and urea.

Arteriole - A very small artery.

Ascites - An abnormal accumulation of serous fluid in the peritoneal cavity caused by increased venous pressure or a decrease of plasma albumin.

Asthma - Commonly called allergic asthma characterized by cough, wheezing, mucous sputum and a sense of constriciton of the chest.

Atopy - An allergy marked by a familial tendency to certain hypersensitivities, as hay fever, asthma, etc.

ATP - Adenosine triphosphate. A compound of one molecule each of adenine and D-ribose with 3 molecules of phosphoric acid. Hydroylsis of it yields energy for muscular and cellular work.

ATPase - An enzyme catalyzing the hydrolysis of adenosinetriphosphate.

Atrophy - A reduction in size of an organ or cell which had previously reached mature size.

Autoradiography - The technique of locating and measuring the distribution of radioactive elements in test material, by means of photographic registration of the emanations from the elements.

Axopodia - Fine, needle-like pseudopodia radiating from the surface of the body of Heliozoans (single cell animals).

Azotobacter - Soil and water bacteria capable of fixing atmospheric nitrogen.

Basal cistern - The subarachnoid space at the base of the brain, divided by the optic chiasma into the cistern of the chiasma and the interpeduncular cistern.

Basal Diet - Fundamental food requirements.

"Beath's Indicators" - Plants which accumulate selenium up to thousands of ppm.

Benzpyrene-hydroxylase - A liver detoxifying enzyme.

Betaine - A substance obtained from sugar-beet molasses. Useful in preventing hepatic cirrhosis.

Bilirubin - A dark green bile pigment formed in the body from hemoglobin, but largely reduced in the liver to bilirubin.

GLOSSARY

Biological Half-Life - The time required for one-half of the remaining administered dose of a substance to be eliminated from the body.

Biopolymers- High molecular weight polymers of biological importance, such as proteins, nucleic acids and polysaccharides.

Blastocyst - A blastula, which is a spherical mass consisting of a central cavity surrounded by a single layer of cells produced by the cleavage of the ovum.

Blastomatogenic - Pertaining to factors which excite cellular multiplication resulting in neoplastic growth.

Blastomere - Any one of the cells into which the fertilized ovum divides.

Blind Staggers - Selenium poisoning disease in sheep and cattle which results from ingestion of forage plants growing on seleniferous soils.

Blood-Brain Barrier - The functional barrier between the blood supplying the central nervous system and the interstitial spaces of the neural tissue.

Blood Catalase - Erythrocyte enzyme which catalyzes the oxidation of hydrogen peroxide to water and oxygen.

BOD - Biological oxygen demand.

Bronchospasm - Temporary narrowing of the bronchi due to violent involuntary contraction of the bronchial muscles.

Cachexia - Weakness and emaciation caused by some serous disease.

Cadaver - A dead body.

Calcium Selenate - $CaSeO_4$.

Carcinoma - An epithelial tumor which is malignant.

Cardiac Blood Pool - Volume of blood in the heart.

Caries - A molecular death of bone or teeth.

Carotene - Any of three isomeric hydrocarbons, of the formula $C_{40}H_{56}$, distinguished by the prefixes α-, β- and γ-. All are synthesized by plants.

Carrier-Free - Describing a radioactive isotope to which more of the stable form of the isotope has been added as a carrier.

Catarrh - Inflammation of the mucous membranes, particularly those of the air passages of the nose and throat, with an exudate containing mucin and epithelial cells.

GLOSSARY

Catheter - A hollow tube for introduction into a cavity through a narrow canal for the purpose of discharging the fluid contents of a cavity.

Cellulose - The principal carbohydrate constituent of the cell wall of plants.

Cerebellum - The inferior part of the brain lying below the forebrain and above the hindbrain.

Cerebrospinal Fluid - The fluid within the cerebral ventricles and between the arachnoid membrane and pia mater of the brain and spinal cord.

Cerebrospinal Scanning - Autoradiography of the brain and spinal cord.

Ceroid Pigment - A substance found in the fat in experimental liver cirrhosis brought about by diet low in methionine.

Ceruloplasmin - A blue, copper-containing serum alpha globulin.

Chlorella Vulgarie - An alga, the source of the antibiotic chlorellin.

Chlorosis - Greensickness; in plants the loss of chlorophyll.

Cholesterol - $C_{27}H_{45}OH$, an unsaturated alcohol of the class of sterole.

Chromatin-RNA Polymerase Complex - Complex of a polymerized nucleic acid present in the chromosomes and carrying the genes.

Chromogen - Any substance which, under suitable conditions, is capable of producing color.

Chronic Selenosis - Long term selenium poisoning.

Chronic Uremia - The long term retention in the blood of urinary constituents due to failure of the kidneys to excrete them.

Ciliate - An organism having threadlike cytoplasmic processes of cells which beat rhythmically, thereby causing locomotion.

Cirrhosis - A chronic, progressive disease of the liver.

Clone - A group of individuals of like genetic constitution obtained by asexual reproduction from a single original individual.

Clonic - Describing a series of movements characterized by alternate contractions and relaxations.

Coagulation Time - The length of time required for shed blood to coagulate.

GLOSSARY

COD - Chemical oxygen demand.

Coenzyme A - A derivative of pantothenic acid which in the presence of a suitable enzyme can accept an acetyl group.

Cofactor - Any metal nutritionally required in trace quantities, participating in reactions, on a molecular level with enzymes.

Collenterator - A phylum of animals which include hydras, jellyfish, sea anemones and corals.

Colloidal Tin - Suspension of elemental tin.

Column Chromatography - A method for the separation of a mixture accomplished by passing a solution through a column of material which effects separation based on molecular weight, adsorptive properties, solubilities, or charge.

Conjunctivitis - Inflammation of the mucous membrane covering the anterior portion of the globe of the eye.

Cortical Pyramidal Cell - A nerve cell of the cerebral cortex.

Cortisone -17-Hydroxy-11 dehydrocorticosterone - A constituent of adenal cortical extract.

Cotyledone - The primary or seed leaf in the phanaerogamic embryo.

Creatinuria - The occurrence of creatine in the urine.

Crista - A crest.

Cysts - A sac with a distinct wall, containing fluid or other material.

Cytochrome Oxidase - An iron-containing oxidase which oxidizes the reduced form of cytochrome C.

Cytoplasm - The protoplasm of a cell other than that of the nucleus.

Decarboxylate - To split off one or more molecules of carbon dioxide from organic acids.

Delirium Tremens - A state marked by distressing delusions, illusions, hallucinations, constant tremor, fumbling movements of hands, insomnia, and great exhaustion.

Dentin - The calcified tissue which forms the major part of a tooth.

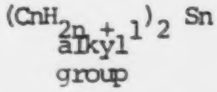
Dermatitis - An inflammation of the skin.

GLOSSARY

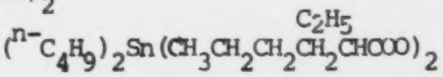
Desquamation - A peeling and casting off, as of the superficial epithelium mucous membranes, renal tubules and the skin.

Desulphydrase - Enzyme which converts cysteine sulfur to H_2S under anaerobic conditions.

Dextran - D-glucose polymer used as plasma substitute.

Dialkyltin - 
$(\underset{\text{alkyl group}}{CnH_{2n+1}})_2\ Sn$

Dibutyltinacetate - $(C_4H_9)_2Sn(CH_3COO)_2$

Dibutyltin di-(2-ethylhexanate) - 
$({}^{n-}C_4H_9)_2Sn(CH_3CH_2CH_2CH_2\overset{C_2H_5}{C}HCOO)_2$

Dibutyltin Oxide (DBTO) - $(C_4H_9)_2SnO$

Diencephalon - That part of the brain containing the thalamic and most of the third ventricle.

Diethyltindichloride -(DETC)- $(C_2H_5)_2SnCl_2$

Dimercaptopropance - BAL(British Anti-Lewisite) - An effective therapeutic agent against both the local and systemic actions of certain arsenic war gases. Also used as antidote to poisoning by certain metals.

Dimethyl Diselenide - CH_3-Se-Se-CH_3

Dimethylglyoxime -$[CH_3C:N:OH]_2$ - A white crystalline powder used for the detection and determination of nickel.

Dimethyl Selenide - CH_3-Se-CH_3

Diphenylacetic Acid - $(C_6H_5)_2CHCOOH$

Dithiocarb - Chelating agent used to treat some metal poisonings; diethyldithiocarbamate.

Diuresis - Increased excretion of urine.

DNA- Desoxyribonucleic acid.

DOPA - Dihydroxyphenylalanine.

GLOSSARY

DTPA - Diethylenetriaminepentacetic acid.

Dyspnea - Difficult or labored breathing.

Dysrhythmia - Any abnormal rhythm such as in brain waves.

Dystrophy - Defective nutrition or abnormal development or degeneration.

Echinodermata - A phylum of invertebrates which includes such animals as the sea stars, sea urchins, sea cucumbers and sea lilies.

Eczema - An acute or chronic noncontagious, itching, inflammatory disease of the skin.

Edema - Excessive accumulation of fluid in the tissue spaces.

Edestin - A globulin type of simple protein; obtained from the seeds of hemp.

EDTA - Ethylenediaminetetraacetic acid.

Electroencephalogram - A graphic record of the minute changes in electric potential associated with the activity of the cerebral cortex.

Electron Spin Resonance - Analytical technique based on the changes in spin properties of electrons in an electrical field.

Electron Transport System - Mitochondrial respiratory chain which oxidizes reduced coenzymes with molecular oxygen as the ultimate electron acceptor.

Electrophoresis - The migration of charged colloidal particles through the medium in which they are dispersed when placed under the influence of an applied electric potential.

Embryopathic - The diseased state of a young organism in the early stage of development.

Emesis - Vomiting.

Emission Spectrophotometry - Analytical technique based on the characteristic emission of light by a compound.

Endemic Fluorosis - Localized poisoning by absorption of toxic amounts of fluorine.

Endometrium - The mucous membrane lining the uterus.

Endoplasmic Reticulum - Cytoplasmic membrane system providing the site for protein synthesis and secretion.

GLOSSARY

Enzyme - A catalytic protein formed by the cell with a specific action of promoting a chemical charge.

Eosinophilia - An increase above the normal number of eosinophil leukocytes in the circulating blood or in the tissues.

Epidermoid Carcinoma - An epithelial tumor which is malignant derived from surface or lining epithelium.

Epididymis - That portion of the seminal duct lying posterior to the testis and connected to it by the efferent ductules of the testis.

Epileptogenic - Producing epilepsy.

Epiphytes - A vegetable parasite growing on the exterior of the body.

Epidemiology - The study of occurence and distribution of disease.

Erythema - A redness of the skin occurring in patches of variable size and shape.

Erythrocytes - The non-nucleated cell of human blood whose oxygen-carrying pigment, hemoglobin is responsible for the red color of fresh blood.

Eschericheria Coli - A normal bacterial inhabitant of man and all vertebrates.

Exophtalmus - Abnormal protusion of the eyeball from the orbit.

Exudative Diasthesis - Selenium deficiency disease in chicks.

Ferrooxidase - Enzyme which converts Fe^{+2} to Fe^{+3} compounds.

Ferrovanadium - Fe_3V_2

Fibrinogen - A protein of the globulin class present in blood plasma.

Fibrin Thrombi - Clots of blood formed within the heart or blood vessels consisting of successive layers of fibrin and red blood cells.

Fibroblast - A stellate or spindle-shaped cell with a large, oval, flattened nucleus and a thin layer of cytoplasm.

Fibrosarcomas - Spindle-cell sarcoma, mature in type, with production of collagenous fibrils.

Focal Necrosis - The localized pathological death of a cell or group of cells in contact with living cells.

GLOSSARY

Follicle - A small secretory cavity or sac.

Formic Acid Dehydrogenase - Enzyme which reduces formic acid to carbon dioxide.

Free Fatty Acid - Long chain monocarboxylic acid of the general formula $CH_3(CH_2)_nCOOH$.

Free Radical - A non-ionic compound, highly reactive and of relatively short life, in which the central element is linked to an abnormal number of atoms or groups of atoms.

Galactolopid - Any phosphorus-free nitrogenous, fatty substance, containing also galactose, found in large amounts in the brain.

Gallium hydroxide - $Ga(OH)_3$.

Gamma-Globulins - A serum fraction protein, contains the antibodies.

Gastric Emptying - Stomach emptying.

Gastrocnemius - A muscle on the posterior aspect of the leg.

Gastroenteritis - Inflammation of stomach and intestine.

Gastrula - An embryo at that stage of its development when it consists of two cellular layers, and a primitive gut.

Gel Filtration - The process of passing through a colloid in solid form.

Gelatin - The product obtained by the partial hydrolysis of collagen, derived from the skin, white connective tissue, and bones of animals.

Gestation - Duration of pregnancy.

Gizzard - The strong muscular stomach of birds used for grinding the food.

Glial Cell - A general term for the fibrous and cellular, non nervous supporting elements of the nervous system, chiefly derived from the ectoderm.

Glomerulin - The tuft of capillary loops projecting into the lumen of a renal corpuscle.

β-Glucuronidase - An enzyme which catalyzes hydolysis of glucuronides.

Glutamate-Oxaloacetate Transaminase - A transfer enzyme which catalyzes the reaction glutamate + oxaloacetate $\rightleftharpoons$ aspartate alphaketogluterate.

GLOSSARY

Glutamate Pyruvate Transaminase - Transfer enzyme which catalyzes the reaction glutamate + pyruvate $\rightleftharpoons$ alanine + alphaketoglutarate.

Glutamic Acid - $COOH-(CH_2)_2CHNH_2COOH$, a dicarboxylic alpha amino acid.

Gold-198 - The gold isotope with atomic weight of 198.

Half-Life - The time during which half of any given amount of a radioactive substance will have undergone transmutation.

Hapten - A partial antigen which reacts with a specific antibody *in vitro* only.

Hebephrenic Schizophrenia - A form in which there is marked silliness, posturing and mannerisms, playing with words and regressive behavior.

Heliozoan - Freshwater rhizopod protozoans that reproduce by binary fission or budding.

Hemoglobin - The repiratory pigment of erythrocytes having the reversible property of taking up oxygen or of releasing it.

Hemopoiesis - The formation of blood.

Hemorrhage - An escape of blood from the vessels.

Hemovanadium - The vanadium present in the blood.

Heparin - A substance occurring in the liver and other tissues, having the property of prolonging the clotting time of blood.

Hepatosis Diactetica - A degeneration or inflammation of the liver which cannot be clearly distinguished clinically. Characterized by diacetic acid in the blood.

Herbivore - An animal which eats plants.

Hexose Diphosphate - One of the hexosephosphates formed during the decompostion of glucose and glycogen in muscle-tissue metabolism.

Hydrated Indium Oxide - $In_2O_3 \cdot x\, H_2O$.

Hydrogen Selenide - H_2Se.

Hydrolysis - Any reaction with water, frequently of the type $AB + HOH \longrightarrow AOH + HB$.

5-Hydroxy-Indole-Acetic Acid - A metabolite of serotonin,

GLOSSARY

β-Hydroxybutyrate - $CH_3CHOHCH_2COOH$. An organic acid that is an intermediary in fat metabolism.

Hypercholesterolemia - Excess of cholesterol in the blood, cells, or plasma.

Hypercoagulation - Excessive clotting or thickening.

Hyperglycemia - Excess of sugar in the blood.

Hyperperistalsis - An increase in the rate and depth of the progressive wave of contraction seen in tubes provided with longitudinal and transverse muscular fibers.

Hypertrophy - An increase in size of an organ, independent of natural growth.

Hypochromic Anemia - Anemia in which the hemoglobin deficiency is comparatively less than that of the red cells.

Hypodermis - The outermost layer of cells of invertebrates, which corresponds to the epidermis.

Hypothermia - Subnormal temperature of the body.

Hysteria - A psychoneurotic disorder characterized by extreme emotionalism, involving disturbances of the psychic, sensory, motor, vasomotor and visceral functions.

Icterus - Pertaining to or characterized by jaundice.

Iliac Bone - The superior broad portion of the hipbone.

Immune Response - Having or producing antibodies to a corresponding antigen.

In Vitro - A process or reaction carried out in test tubes, culture, etc.

In Vivo - In the body.

Indicator Plants - Plants which are indicative of the mineral content of an area.

Indium-111 - Isotope of the element indium.

Indium-111 Transferrin -

Indium-113M Diethylenetriaminepentacetic Acid - An indium chelate used for diagnostic organ scanning.

Indium-113M EDTA - An indium chelate used for diagnostic organ scanning.

GLOSSARY

Indium-113M Ferric Hydroxide - Mixture used for diagnostic organ scanning.

Indium-113M Glutathione - Injection mixture used for diagnostic organ scanning.

Indium-113M Sulfur Colloid - Suspension of radioactive ^{113M}In and sulfur, used for organ scanning.

Indium Antimonide - $InSb$.

Indium Chelates - Chemical complex between indium and chelating agents.

Indium Chloride - $InCl_3$.

Indium Chondroitin Sulfate Colloid - Suspension used for diagnostic organ scanning.

Indium Colloid - Gelatin dispersion of elemental indium used for diagnostic organ scanning.

Indium Human Serum Albumin - Injection mixture used for diagnostic organ scanning.

Indium-Iron-Ascorbic Acid Complex - Injection mixture used for organ scanning.

Indium Nitrate - $In_2(NO_3)_3$.

Indium Phosphate Colloid - $InPO_4$ dispersed in a gel matrix.

Indium Triacetate - $In(CH_3COOCH_3)_3$.

Induction - The morphological effect brought about by the action of one tissue upon another.

Interferon - A heat-stable soluble basic antiviral protein of low molecular weight produced by cells exposed to the action of a virus.

International Units - An arbitrarily defined weight of an international standard of reference adopted by the Permanent Commission on Biological Standardization of the League of Nations.

Intracranial - Within the skull.

Intragastric - Within the stomach.

Intraperitoneal - Within the peritoneum.

Intratracheal - Within the trachea.

Intravenous - Within the vein.

GLOSSARY

Ionic Indium - In^{+3}.

Iron-Dextran -

Iron(III) Hydroxide Selenite - $FeOHSeO_3$.

Iron(II) Selenide - FeSe.

Keratin - Any of a group of albuminoids or scleroproteins characteristic of horny tissues, hair, nails, feathers, etc.

α-Ketoglutaric Acid - $COOH(CH_2)_2COCOOH$. A dibasic keto acid.

Kwashiorkor - A deficiency disease, probably of animal protein.

Lacrimation - Normal secretion of tears.

Lactalbumin - A simple protein contained in milk which resembles serum albumin.

$L.C._{50}$ - Lethal concentration, median.

$L.D._{LO}$ - Minimum lethal dose.

$L.D._{50}$ - Median lethal dose.

Leaf Rust - A rust disease of plants that affects primarily the leaves.

Legumes - A vegetable used for food.

Lesion - The alteration, structural or functional, due to injury.

Leucopenia - A decrease below the normal number of leucocytes in the peripheral blood.

Lichen - Any of numerous plants made up of an algae and a fungus growing in symbiotic association on a solid surface.

Limb Bud - The embryonic proliferation of cells which will form the limbs.

Lipase - A fat-splitting enzyme contained in the pancreatic juice, in blood plasma and many plants.

Lipid Peroxidation - A process of incorporating the bivalent C-O-O- group into proteins or carbohydrates that are the components of living cells.

Lipoprotein - Conjugated proteins consisting of simple protein combined with a lipid.

GLOSSARY

Lucid Catatonia - A disorder marked by catalepsy.

Lymphocytes - A cell formed primarily in lymphoid tissue.

Lymphoid Leukemia - A form of leukemia, acute or chronic, in which the predominating cell type belongs to the lymphocyte class.

Lymphomas - A group of malignant or premalignant conditions of lymphoid tissue in which splenomegaly and lymphadenopathy are usually present.

Lysozyme - An enzyme found in tears, leukocytes, mucous secretions, egg albumin and many plants.

Macromolecules - large molecules.

Macrophage - A phagocytic cell, not a leukocyte, belonging to the reticuloendothelial system.

Magnum - Large, as in foramen magnum.

Malphigian Layer - The former name of germinative layer of the epidermis.

Maneb - A plant fungicide.

Mannitol - $CH_2OH.OHCH\cdot HOCH\cdot HCOH\cdot HCOH\cdot CH_2OH$. A hexahydric alcohol from manna and other plant sources; used to measure the rate of glomervlar filtration.

Maxillary Antrum - The maxillary hollow or cavity.

Medullary Layer of Adrenal - The central area of the adrenal gland.

Melancholia - A form of mental disorder characterized by extreme depression, fear, brooding, and painful delusions.

Menostasis - A suppression of the menstrual flow.

Mesenchyme - The portion of the mesoderm that produces all the connective tissues of the body, the blood vessels, and the blood, the lymphatic system and the heart.

Mesophyll - The parenchyma between the epidermal layers of a foliage leaf.

Metalloenzyme - An enzyme containing metal as an inherent portion of its molecule.

Metamorphosis - A structural change or transformation.

Metastasis - The transfer of disease from a primary focus to a distant one by conveyance through the blood or lymph vessels.

GLOSSARY

Methandrostenolone - A carcinogenic synthetic steroid.

Michaelis Laws - A relationship that measures the kinetics of an enzyme reaction.

Microcurie - The amount of a radioactive substance which undergoes 3.7×10^4 disintergrations/second.

Micrograms - μg; one millionth of a gram.

Microns - One-millionth of a meter; μ.

Microsome - A noncommittal for any granule found in a cell.

Millimolar - One thousandth of a mole.

Mitochondria - Cytoplasmic organelles present in all cells; energy metabolism takes place in them.

Mitotic Figures - A series of visible events during mitosis, e.g. spindle and asterr, chromosomes.

Mitotic Index - The number of dividing cells per thousand cells.

Molar - Moles of solute in a definite volume of solution, usually 1 liter.

Monoamine Oxidase - Enzyme which oxidatively deaminates the catecholamines, morepinephrine and epinephrine.

Monocytosis - Increase in the number of large mononuclear leukocytes in the peripheral circulation.

Monogastric - One stomach.

Murphy Lymphosarcoma - A malignant lymphoma that tends to metastazize freely.

Muscle Tremor - Slight, oscillating, rhythmic muscular contractions.

Muscular Dystrophy - A progressive, familial hereditary disorder, marked by atrophy and stiffness of the muscles.

Myelin - The white, fatty substance forming a sheath of some nerves.

Myeloid Leukemia - Leukemia in which the predominant cell types belong to the granulocytic series.

Myopathy - Any disease of the muscles.

GLOSSARY

Myopathy - Any disease of the muscles.

Myocardial Infarction - A region of necrosis in the heart tissue due to complete interference with blood flow.

Myocardial Schemia - Local diminution in the blood supply, due to obstruction of inflow of arterial blood.

Myocardial Trabeculae - The interlacing muscular columns projecting from the inner surface of the ventricles of the heart.

Myotrophic Steroid - A steroid which acts directly upon muscle.

NADPH - Reduced nicotine adenine dinucleotide phosphate, a redox coenzyme.

Narcosis - A state of profound stupor, unconsciousness, or arrested activity.

Nasopharynx - The space behind the posterior nares and above a horizontal plane through the lower margin of the palate.

Nematode - A worm of the class Nematoda true roundworms.

Neoplasms - Any new growth.

Nephrotoxic - Destructive to the kidney cells.

Neutro Phil - The polymorphonuclear leukocyte of the blood, which contains neutrophil granules in its cytoplasm.

Newcastle Disease - An acute virus disease of fowls characterized by pneumonia and encephoelomyelitis.

Nickel Carbonate - $NiCO_3$.

Nickel Carbonyl - $Ni(CO)_4$.

Nickel Chloride - $NiCl_3$.

"Nickel Itch" - Dermatitis at area of contact with nickel.

Nickel-63 - Radioisotope of nickel.

Nicotinamide - $C_5H_4N \cdot CONH_2$.

Niphen - Trade name of a phenol derivative used for athlete's foot or ringworm.

Nitrification - The conversion of the nitrogen of ammonia and organic compounds into nitrites and nitrates.

GLOSSARY

Nitrogen Fixation - Conversion of free nitrogen in the air into compounds, such as ammonia and nitric acid.

Node of Ranvier - Regular, local constrictions of myelinated nerve fibers of the peripheral nerves.

Norepinephrine - Chemical transmitter at sympathetic nerve endings with the structure.

Nucleotide - The combination of a purine or pyrimidine base with a sugar and phosphoric acid.

Nutritional Muscular Dystrophy (NMD) - A disease characterized by progressive wasting of the muscles aggravated by improper diet.

Occipital Focus - The principle location of a disease in the occipital bone.

Omasum - The third compartment of the stomach of a ruminant.

Oneiroid Catatonia - A severe type of dementia praecox.

Oocyte - An egg cell before the completion of the maturation process.

Opisthotonos - A condition in which, from a tetanic spasm of the muscles of the back, the head and lower limbs are bent backward and the trunk is arched forward.

Oratic Acid - $C_5H_4N_2O_4$. A pyrimidine precursor in animal tissues.

Organelles - A specialized structure or part of a cell having a definite function to perform.

Osmotic Diuresis - A substance producing diuresis because of the osmotic effect of the unabsorbed fraction in the renal tubules with resulting loss of water.

Osteoblastoclastoma - Bone-forming cell.

Osteochondroma - A tumor originating in bone or cartilage occasionally from other structure, which histologically contains both bone and cartilage.

Osteodystrophy - Any defective bone formation.

Ovabain - $C_{29}H_{44}O_{12} \cdot 8H_2O$. A glycoside which inhibits ATPase.

GLOSSARY

Ovalbumin - The albumin of egg white.

Ovine - Relating to sheep.

Oxidative Phosphorylation - The esterification of compounds with phosphoric acid in the presence of oxygen.

Palantine Tonsils - One found on each side of the throat.

Paranoid Schizophrenia - A form in which delusions of persecution or of grandeur or both, hallucinations, and ideas of reference predominate and sometimes are systematized.

Parenchyma - The essential or specialized part of an organ as distinguished from the supporting connective tissue.

Paroxysm - The periodic increase or crisis in the progress of a disease.

Pectoral Muscle - Muscle, which connects the arm and the chest.

Pelt - skin of a fur-bearing animal.

Peroxidation - A process of incorporating the bivalent -O-O- group into a compound.

Phagocyte - A cell having the property of engulfing and digesting foreign or other particles or cells harmful to the body.

Phagocytosis - Ingestion of foreign or other particles, principally bacteria, by certain cells.

Pharynageal Mucous Sheath - A lining of mucuos in the region of the pharynx.

1, 10-Phenanthroline - Enzyme inhibitor which acts by combining with required metal cofactors.

Phenoxybenzamine - N-phenoxy-isopropyl-N-benzyl β-chloroethylamine, an adrenergic blocking agent.

Phospholipid Monolayer - A single layer of a type of lipid, which is an ester of phosphoric acid and contains, in addition, one or two molecules of fatty acid; an alcohol, and a nitrogenous base.

Photosynthesis - The process by which simple carbohydrates are synthesized from carbon dioxide and water by the chloroplasts of living plant cells in the presence of light.

GLOSSARY

Pineal - Referring to the pineal gland.

Pituitary - A small rounded organ attached to the floor of the brain by a stalk. It is the master gland of internal secretion.

Placental Scanning - Autoradiography of the placenta.

Plankton - General term for free-floating plants and animals in sea water.

Plantararch -The arch of the sole of the foot.

Platelet - Spheroidal or ovid light-gray bodies found in blood; an important factor in blood coagulation.

Pleistocene - The earlier epoch of the Quartenary or the corresponding system of rocks.

Pleura - The serous membrane enveloping the lung.

Polycythemia Vera - A rare disease in which the red blood cells are greatly increased in number, with an absolute increase in the total mass of red cells/kg of body weight.

Polydactyly - The existence of supernumerary fingers and toes.

Polystyrene-Latex - A clear lightweight plastic prepared by reaction and polymerization of ethylene and benzene.

Polyvinyl Chloride - $(CH_2CHCl)_n$; a polymer of vinyl chloride.

P.P.B. - Parts per billion.

P.P.M. - Parts per million.

Precentral Motor Cortex - The outer gray portion of the cerebrum in front of central fissure of the brain.

Pressor Effect - An effect which produces a rise in blood pressure.

Primary Carcinoma - The principal location of malignancy.

Primary Selenium Indicators - Plants which absorb selenium from the soil.

Proline - $C_5H_9O_2N$; an amino acid.

Proteolytic Enzymes - Enzymes converting proteins into simpler substances.

GLOSSARY

Proximal Convoluted Tubule - The part of the renal tubule which lies in the cortex of the kidney nearest the renal corpuscle.

Pseudocholinesterase - An enzyme which catalyzed the hydrolysis of acetylcholine but which differs from cholinesterase in that it is nonspecific and hydrolyzes esters other than choline esters.

Pseumosclerosis - An affection similar in symptoms to multiple sclerosis of the nervous system.

Psoriasis - A chronic inflammatory skin disease.

Pulmonary Artery - The artery leading from the right ventricle of the heart to the lungs.

Pyridoxal Phosphate - The 4-aldehyde of pyridoxine, an essential component of enzymes concerned with amino-acid decarboxylation with transamination.

Pyrrole Rings - NH·CH:CH·CH:CH. A colorless liquid occurring in bone oil. Many complex natural compounds, such as hemoglobin and chlorophyll,contain pyrrol components.

Radialized Larvae - Larvae subjected to radiation.

Radiocolloid - Any colloidal aggregate of radioactive substances.

Radioindium - Any radioactive isotope of Indium.

Radionuclide - A radioactive atom which is characterized by the number of protons in the nucleus.
Radiopaque - Not transparent to the X-ray.

Radiopharmaceuticals - A radioactive drug used for diagnostic or therpeutic purposes.

Redox Agent - An agent which brings about a reduction-oxidation reaction, state, or system.

Reductive Methylation - Introduction of the methyl group into a compound.

RES - Reticuloendothelial system.

Respiratory Center - A region of the Medulla oblongota which regualtes respiratory movements.

GLOSSARY

Reticulocyte - An immature or young erthrocyte containing ribonucleoprotein as a granular or filamentous network.

Reticulocytosis - Condition in which reticulocytes are present in excess in the peripheral blood.

Reticuloendothelial System - Pertaining to cells which are grouped under the term macrophage, which includes all the phagocytic cells of the body, escept the leukocytes.

Retinitis - Inflammation of the retina.

Rhabdomyo-Sarcoma - A malignancy occurring in the rodlike structures in the retinules in the compound eyes of arthropods.

Rheumatoid Arthritis - A chronic arthritis of unknown origin; affects multiple joints, producing constitutional effects such as debility, weakness, and loss of weight.

Rhinitis - Inflammation of the nasal mucous membrane.

Ribonuclease - An enzyme present in various body tissues which depolymerizes ribonucleic acid to give mononucleotides.

Ribosomal - Connected with the cytoplasmic granules that are sites of protein synthesis.

RNA - Ribonucleic acid.

Rous Sarcoma Virus - A chicken sarcoma.

Rumen - First compartment of the stomach of the ruminant, where food is temporarily stored.

Ruminant - One of an order of animals possessing an arrangement of the fore-stomach whereby food is regurgitated and remasticated.

Sarcoma - A malignant tumor composed of cells derived from nonepithelial tissues, mainly connective tissue.

Schizophrenia - One of a group of psychotic reactions.

Scintigram - A printed or penned record, consisting of horizontal rows of short vertical lines, variably spaced, which in the aggregate shows the distribution of a radioactive tracer substance, in intact tissue, and also the profile of the tissue.

Saturation Binding - Connecting compounds by adding one to the double bond of an organic compound.

GLOSSARY

Sclerosis - Hardening, especially of a part by overgrowth of fibrous tissue.

Secondary Selenium Indicators - One of a group of plants which absorb a limited amount of selenium from the soil.

Sedimentary Rock - Rock which is formed by deposition.

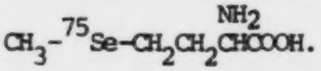
Selenate - A salt of selenic acid, SeO_4^{-2}.

Selenious Acid - H_2SeO_3.

Selenite - A salt of selenious acid, SeO_3^{-2}.

Selenium-75 - Radioactive isotope of selenium.

Selenium-75-Selenomethionine - Radioactive selenium analog of methionine,



$CH_3-{}^{75}Se-CH_2CH_2\overset{NH_2}{C}HCOOH.$

Selenium-75-Sodium Selenite - $NA_2Se^{75}O_3$.

Selenium Dioxide - SeO_2.

Selenium Oxychloride - SeClO.

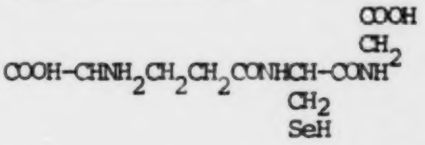
Seleno-Amino Acids - Amino acids containing Se.

Selenocyanate - SeCNO.

Selenocystathionine - Selenium analog of xystathionine, $HOOCCHNH_2CH_2-Se-CH_2CH_2CHNH_2COOH$.

Selenocystine - Selenium analog of the amino acid, cystine, $HOOC\cdot CHNH_2CH_2-Se-Se-CH_2CH_2CHNH_2COOH$.

Selenogluthathione - Selenium analog of gluthathione,



$$COOH-CHNH_2CH_2CH_2CONH\underset{\underset{SeH}{CH_2}}{C}H-CONH\overset{\overset{COOH}{CH_2}}{}$$

6-Selenopurine - Selenium-substituted purine,

Selenotaurine - Selenium analog of taurine, $H_2NCH_2CH_2SeO_3H$.

Selenotrisulfide - SeS_3

GLOSSARY

Serotonin - A substance present in the blood stream which imparts vasoconstrictor activity to the vascular system.

Serpentine Soil - Soil containing hydrous magnesium silicate.

Serum - The amber colored fluid which exudes from coagulated blood as the clot shrinks, and then no longer contains fibrinogen.

Siderosclicosis - Diffuse fibrosis of the lungs due to prolonged inhalation of dusts containing silicon dioxide and iron salts.

Sinus Venosus - The chamber of the vertebrate heart to which the veins return blood from the body.

Sinusitis - Inflammation of a sinus.

Sludge - Sewage deposit.

Sodium-Calcium Channel -

Sodium Metavanadate - $NaVO_3$.

Sodium Selenate - Na_2SeO_4.

Spectral Absorption - The absorption of a selective portion of radiation, after it has passed through some absorbing substance.

Spermatogenesis - The phenomena involved in the production of mature male germ cells.

Stanosis - Tin poisoning.

Stannous Chloride - $SnCl_2$.

Sterol - Any saturated or unsaturated alcohol derived from cycloplatanoperhydrophenanthiene.

Subacute - The stage of a disease when it is intermediate between an acute and a chronic form.

Subcellular - Below the cellular level, e.g. nuclear, mitochondria, etc.

GLOSSARY

Subcutaneous - Beneath the skin.

Subdermal - Beneath the dermis.

Succinate - A salt of succinic acid. ($COOH \cdot CH_2 \cdot CH_2 \cdot COOH$).

Sulfanilamide - $NH_2C_6H_4SO_2NH_2$. Exerts a potent antibacterial effect against many organisms, being of chemotherapeutic value.

Sulfhydryl Group - The univalent radical SH, usually attached to a carbon chain.

Supernate - The fluid which remains after the removal of suspended matter by centrifugation or other physical or chemical means.

Sympathetic Nervous System - The thoracolumbar division of the nervous system supplying and exerting a regulatory influence over involuntary muscle, glands, viscera, etc.

Tc_{Lo} - Lowest toxic concentration.

Telophase - The final stage of mitosis in which the chromosomes reorganize to form an interstage nucleus.

"Test" Cells - Cells under examination.

Testicular Parenchyma - The specialized part of the testicle.

TET - Triethyl tin, $(C_2H_5)_3$ SnX.

Tetany - A disease characterized by intermittent, bilateral, painful tonic spasms of the muscles, in children and young adults.

Tetraethytin - $(C_2H_5)_4Sn$.

Thioctic Acid - Any of several dithio-n-octanoic acids, all of which are more or less able to promote oxidative decarboxylation of pyruvic acid by certain bacteria.

Thrombocytopenia - A condition in which the blood platelets are functionally abnormal.

Thymus - An organ situated in the beneath the breast bone composed of lymphatic tissue.

Tissue Calcification - Deposition of calcium salts in tissue.

Transferrin - A pseudoglobulin of blood combining with two atoms of ferric iron to form a compound which serves to transport iron in blood.

GLOSSARY

Transudation - The passing of fluid through a membrane, especially of blood serum through the vessel walls.

Trichomonar Vaginitis - A genus of flagellate protozoa found in the vagina.

Triethyltin - $(C_2H_5)_3SnX$.

Triglyceride - An ester of glycerin in which all three hydroxyl groups of the latter are esterified with an acid.

Tributyltin Acetate - $(C_4H_9)_3SnOCOCH_3$.

Trimethylselenonium Ion - $Se(CH_3)_3^+$

Tri-n-Octyl Tin - $(n\text{-}C_8H_{17})_3SnX$.

Triphenyltin Acetate - $(C_6H_5)_3SnCH_3COO$

Tryptophan - α-Amino-β-indole propionic acid, an essential amino acid.

Tubificid - Any of a family of aquatic worms that do not reproduce asexually.

Tunicates - Members of degenerate marine chordate animals that have clefts in the walls of the gills and a heart able to reverse the direction of the blood flow.

Tyrosine - $P\text{-}HO\cdot C_6H_4CH_2CH(NH_2)COOH$; an amino acid widely distributed in proteins.

Ultrasonification - The application of waves of high frequency and moderate intensity for treatment of cells.

Urea Cycle - The production of urea from nitrogen derivatives.

UV Spectrophotometry - Measuring the relative intensities of light in the ultraviolet region.

Uvular Edema - A swelling of the conical appendix hanging from the free edge of the soft palate.

Vacuole - A clear space in a cell.

Vanadium-48 - Radioisotope of vanadium.

Vanadium Carbide - VC.

Vanadium Pentoxide - V_2O_5

GLOSSARY

Vanadium-48-Trichloride - Radioactive form of VCl_3.

Vanadocytes - Cells containing vanadium.

Vascular Shock - Shock caused by paralysis and dialatim of small arteries, arterioles and capillaried with no loss of blood volume but increased vascular-free capacity.

Vasoconstriction - The constriction of blood vessels.

Vasodilation - Dilatation of the blood vessels.

Vasospasms - Vasoconstriction.

Venous Oxygen Capacity - The capacity of the blood for replacing oxygen with carbon dioxide.

Vitamin C - Ascorbic acid; necessary for maintenance of intercellular substance of teeth, bones and vascular walls.

Vitamin E - Tocopherol. This vitamin appears to be essential for the maturation and deferentiation of certain cells.

Vitreous Humor - The transparent gelatinlike substance filling the greater part of the globe of the eye.

White Muscle Disease (WMD) - A myopathy that occurs in young ruminants often due to a deficiency of selenium.

Yoshida Sarcoma - An asciter of rats. Used to test the efficiency of cancer therpeutic drugs.

Zineb - A plant fungicide.

Zooplankton - Animal life of the plankton.

Zygote - An organism produced by the union of two gametes.